For Reference

NOT TO BE TAKEN FROM THIS ROOM

Ex libris
universitatis
albertensis

THE UNIVERSITY OF ALBERTA

IDENTIFYING MATHEMATICAL COMPETENCIES FOR THREE SELECTED TRADES

by

© GILLES CHARLES VERRET

A THESIS
SUBMITTED TO
THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF EDUCATION
IN
VOCATIONAL EDUCATION

DEPARTMENT OF INDUSTRIAL AND VOCATIONAL EDUCATION

EDMONTON, ALBERTA

FALL, 1977

DEDICATION

To my wife Olga and our children, Roger and Christine, whose support, patience, and understanding helped make this study possible.

ABSTRACT

The purpose of this study was to determine and report on the mathematical knowledges and skills that certificated journeymen from each of three selected trades considered necessary to possess in order that they may be able to practice their trade in a successful manner. The three trades selected for the study were the Motor Mechanic trade, the Heavy Duty Mechanic trade, and the Welder trade.

The study arose out of reports originating from sources both within and outside of educational circles expressing concern about the suitability and adequacy of mathematics instruction offered by the publicly supported schools. Some degree of dissatisfaction with the level of mathematical knowledge and skill achieved by students enrolled in high school vocational education programs had been expressed from time to time by teachers and administrators of these programs. These concerns had resulted in the planning of an "Associate Studies" program by one urban composite high school. This program consists of a cluster of vocationally related general education subjects whose curricular objectives were aimed at meeting the needs of students enrolled in vocational education programs of studies.

The study, in dealing with the general problem of mathematical competencies required by journeymen attempted to answer the following questions:

1. What mathematical knowledges and skills do certificated journeymen consider necessary to possess in order that they may be able to practice in a successful manner the trades of Motor Mechanic, Heavy Duty Mechanic, and Welder?

2. What mathematical knowledges and skills do certificated

journeymen consider desirable to possess in order that they may be able to practice in a successful manner the trades of Motor Mechanic, Heavy Duty Mechanic, and Welder?

The design of the study called for opinion data to be obtained from certificated journeymen sampled from each of three discrete populations, namely, Motor Mechanics, Heavy Duty Mechanics, and Welders. Each of these three populations was stratified as to the function performed by the journeymen. These functions were placed into the following three groups: Supervisors; Journeymen; Instructors.

The data for the study were obtained by means of a questionnaire in the form of a mathematical checkoff list consisting of 45 mathematical competency items which respondents were asked to rate on a three point Likert-type scale as "necessary", "desirable", or "not needed".

The data presented in the study show that 18 mathematical knowledge and skill items were judged "necessary" by 50 percent or more of the respondents from the Motor Mechanic sample; 20 items were judged "necessary" by 50 percent or more of the respondents from the Heavy Duty Mechanic sample; and 25 mathematical knowledge and skill items were judged "necessary" by 50 percent or more of the respondents from the Welder sample.

The study presents data in the form of compound bar histograms and proposes a method of using these histograms to design mathematics courses whose curricular objectives will meet the needs of students enrolled in the high school vocational education programs in Automotives and Welding.

ACKNOWLEDGEMENTS

The writer wishes to express deep and sincere appreciation to those people who contributed to the development and completion of this study.

In particular, recognition is due to my supervisor, Dr. C. H. Preitz whose encouragement and understanding served to make this thesis a learning experience.

Appreciation is also due to Dr. D. R. Young and Dr. T. P. Atkinson who graciously consented to serve on my thesis committee.

Recognition is due to the administration of St. Joseph Composite High School whose "Associated Studies" program provided the genesis of this study.

Finally, special thanks are extended to Mary Jane Pomerleau for her untiring efforts in typing the thesis.

G. C. V.

TABLE OF CONTENTS

CHAPTER PAGE

I. THE PROBLEM 1

Introduction 1

Need for the Study 4

Purpose of the Study 6

Delimitations and Limitations of the Study 7

Significance of the Study 9

Definitions of Terms 9

Population and Sample 15

Methodology 17

II. REVIEW OF RELATED LITERATURE 20

Introduction 20

Academic Content of Occupations 22

Mathematical Requirements of Occupations 23

Mathematics Programs: Evaluations and Comments 26

Purposes and Objectives of Mathematics Instruction 32

Review of Textbooks and Trade Reference Works 39

Summary of the Review of Related Literature 46

III. DESIGN OF THE STUDY 47

Description of the Populations 47

Sampling Procedure 48

The Research Instrument 49

Pilot Study 52

Distribution of Research Instruments 53

Data Tabulation for Motor Mechanics Sample 56

Data Tabulation for Heavy Duty Mechanics Sample 67

Table of Contents (contd.)

CHAPTER PAGE

Data Tabulation for Welders Sample 78

Data Tabulation for Three Samples Combined 89

Comments and Mathematical Shortcuts 92

IV. PRESENTATION OF FINDINGS 95

The Histograms 95

Proposed Uses of Histograms 105

V. SUMMARY, CONCLUSIONS, OBSERVATIONS, IMPLICATIONS, AND RECOMMENDATIONS 107

Summary of the Study 108

Conclusions 112

Observations 112

Implications and Recommendations 114

BIBLIOGRAPHY 116

APPENDIX A The Research Instrument 122

APPENDIX B The Covering Letter 127

VITA 129

LIST OF TABLES

Table Page

I Numbers and Percent Proportions of Questionnaire Returns by Sample Subgroup 55

Motor Mechanics Sample

II Mathematical Knowledges and Skills Frequencies for Supervisor Group - Motor Mechanics Sample 57

III Mathematical Knowledges and Skills Frequencies for Group A[1] Journeymen - Motor Mechanics Sample 59

IV Mathematical Knowledges and Skills Frequencies for Group B[2] Journeymen - Motor Mechanics Sample 61

V Mathematical Knowledges and Skills Frequencies for Instructor Group - Motor Mechanics Sample 63

VI Mathematical Knowledges and Skills Frequencies and Percentages for Motor Mechanics Sample 65

Heavy Duty Mechanics Sample

VII Mathematical Knowledges and Skills Frequencies for Supervisor Group - Heavy Duty Mechanics Sample 68

VIII Mathematical Knowledges and Skills Frequencies for Group A[1] Journeymen - Heavy Duty Mechanics Sample 70

IX Mathematical Knowledges and Skills Frequencies for Group B[2] Journeymen - Heavy Duty Mechanics Sample 72

X Mathematical Knowledges and Skills Frequencies for Instructor Group - Heavy Duty Mechanics Sample 74

---

[1] Group A = Journeymen having 5 years or less of experience in their trade.

[2] Group B = Journeymen having more than 5 years of experience in their trade.

Table Page

XI Mathematical Knowledges and Skills Frequencies and Percentages for Heavy Duty Mechanics Sample 76

Welders Sample

XII Mathematical Knowledges and Skills Frequencies for Supervisor Group - Welders Sample 79

XIII Mathematical Knowledges and Skills Frequencies for Group A[1] Journeymen - Welders Sample 81

XIV Mathematical Knowledges and Skills Frequencies for Group B[2] Journeymen - Welders Sample 83

XV Mathematical Knowledges and Skills Frequencies for Instructor Group - Welders Sample 85

XVI Mathematical Knowledges and Skills Frequencies and Percentages for Welders Sample 87

Three Samples Combined

XVII Mathematical Knowledges and Skills Frequencies and Percentages for Three Samples Combined 90

---

[1] Group A = Journeymen having 5 years or less of experience in their trade.

[2] Group B = Journeymen having more than 5 years of experience in their trade.

LIST OF FIGURES

Figure Page

1. Mathematical Knowledges and Skills Percentages For Motor Mechanics 97

2. Mathematical Knowledges and Skills Percentages For Heavy Duty Mechanics 99

3. Mathematical Knowledges and Skills Percentages For Welders 101

4. Mathematical Knowledges and Skills Percentages For Motor Mechanics, Heavy Duty Mechanics, and Welders Combined 103

CHAPTER 1

THE PROBLEM

Introduction

The enactment of the Technical and Vocational Training Assistance Act marked the beginning of a new era in the long history of Federal Government participation in technical and vocational education in Canada. Cohen, (1964) traced the history of vocational education in Canada and enumerated the developments which led up to the passing of the Act in December, 1960:

> The financial involvement of the Federal Government in Vocational Training goes back half a century to the years immediately preceding the first world war. The Agriculture Instruction Act of 1913 provided $10,000,000 for projects in agricultural training. The Technical Education Act of 1919 did the same for industrial and technical education and introduced the principle of matching provincial capital expenditures. The Vocational Training Coordination Act of 1942 established the added principle of federal contribution to operational expenditures. This act was replaced by the Technical and Vocational Training Assistance Act of 1960.
>
> 1. The acceleration of technology which has been particularly apparent in the post war years, has brought a growing demand for workers with higher levels of education and training and with the ability to adapt to a continually changing environment. The employment group embracing skilled, professional, and white collar jobs has been growing faster and is larger in numbers than the group consisting of semi-skilled and unskilled jobs.
>
> 2. Canada has been faced with the serious problems of young people leaving school too early. The majority of youths who have been entering the labor force have not had sufficient education to meet the needs of industry.
>
> 3. The 15 to 19 year-old age group has been growing rapidly since 1960 and will continue to do so until 1970.

> 4. The level of education and training of those already in the labor force is also cause for concern. About 43 p.c. [percent] of the work force in 1960 had an education of grade 8 or less. (pp. 737 - 738)

The Act (Statutes of Canada, 1961) which resulted from the recognition of the above factors provided for Federal Government assistance for nine different kinds of programs. The one which concerned this study referred to secondary schools:

> The minister may, with the approval of the Governor in Council, enter into an agreement with any province, for a period not exceeding six years, to provide for the payment by Canada to the province of contributions in respect of the costs incurred by the province in undertaking a program of technical and vocational training in the province . . . for the training of persons in technical or vocational courses given in regular secondary schools in the province where such training is given as part of the regular secondary school program. (p. 39)

Alberta entered into such an agreement with the Federal Government and the massive building program which ensued resulted in the opening, in the fall of 1963, of vocational high schools in the larger population centres throughout the province.

The new vocational high schools were organized as comprehensive schools which offered, in addition to vocational education, a full range of programs including academic university-matriculation, general non-matriculation, as well as a wide choice of optional subjects. Most of the vocational subjects, especially the ones which were of a technical nature, were half-day programs yielding fifteen or twenty credits per year in Grades 11 and 12. Students enrolled in vocational programs spent approximately half of their school day in the vocational subject while the other half of the day was devoted to the academic or general subjects needed to complete the requirements for the Alberta High School

Diploma. This seemed to be an adequate arrangement because it provided for acquisition of skills specific to an occupation while still doing justice to the traditional general knowledge objectives of education.

The academic and general subjects offered by the vocational high schools held a position in relation to the vocational subjects which went much beyond simply providing a balancing component of general education. This was due to the fact that many of the vocational subjects dealt with technologies which were founded upon the academic disciplines, notably the mathematics and the physical sciences. These subjects were perceived as necessary studies parallelling the vocational offerings, often to the point of being prerequisite to their successful mastery. Kidd and Leighbody (1955) referred to these supporting disciplines as "related subjects" and discussed approaches and strategies teachers of these subjects were to employ to insure that they were presented to the students as they applied to the various vocational subjects (pp. 177 - 188). Teachers of vocational subjects were therefore keenly interested in the quality of instruction in academic and general subjects and in the appropriateness of their curriculum content for vocational education students.

Of the academic and general subjects, the one that seemed to arouse the most concern on the part of vocational educators was mathematics. One can only speculate as to why mathematics was singled out from among the other related subjects but it may have been because of the importance that basic mathematical skills have in subjects that are trade oriented, or because, shortly after the initiation of the high school vocational education programs, mathematics instructional objectives and curriculum content underwent a change in emphasis signalled by the advent of "Modern Mathematics".

In order to more fully appreciate the implications of the change of emphasis referred to above, it was thought advantageous to examine some of the considerations which affect selection of subject matter for curriculum content. Smith, Stanley and Shores (1957) presented five standards that had been used by curriculum workers to guide their decisions about subject matter selection. The first standard related to the significance of subject-matter to an organized field of knowledge; does it fit into a series of specialized sequential courses? The second standard was concerned with survival; had the subject matter withstood the test of time? Thirdly, was the subject matter useful in preparing people for the performance of activities thought important to life? Fourthly, was the subject matter interesting to the learner? Did it meet his "needs"? The fifth standard asked the question "does the subject-matter contribute to the growth and development of a democratic society" (pp. 133 - 137). These principles have been applied either singly or in combination to govern decision-making in the area subject-matter selection for curriculum content. The change in emphasis referred to above was manifested in increasing concern with satisfying the first criterion when selecting curriculum content in mathematics. Worth (1964) wrote as follows in The A.T.A. Magazine:

> In essence, what is being proposed by writers like Jerome Bruner in Process of Education is that what is taught should emphasize the structure of the subject . . . Here in Alberta the emphasis upon structure is beginning to make itself felt through the new elementary mathematics program based on the Seeing Through Arithmetic texts. (p. 7)

Need for the Study

In recent years, as evidenced by reports in the news media, periodical articles, and reports of research findings, there has been

mounting public concern about the adequacy of mathematics instruction and the appropriateness of mathematics curriculum content in the publicly supported schools. As an example, a report in Edmonton Journal entitled "New Math Just Doesn't Add Up" (July 19, 1976) stated in part: "The new math has been a wipeout, mainly because teachers don't understand it and the textbooks they use are a rip-off" (p. 1). The controversy raged over a value judgment as to why mathematics should be learned. At one extreme is the view expressed by Carmichael (1922) who stressed the "larger human worth of mathematics" and stated that "mathematics is autonomous . . . logically, the mathematical sciences can be developed in complete independence of other sciences" (p. 462). An opposite view was expressed by Kline (1958) who wrote:

> It seems curious to me that when the modernists talk about applications they make no mention of the application of mathematics to mechanics, sound, light, radio, electricity, plasticity, chemistry, chemical physics, physical biology, and the various branches of engineering. (pp. 420 - 421)

In short, was mathematics to be learned as a mental exercise purely for its own sake, or was it to be learned for application as a tool in everyday life and work?

Even if one were to have accepted the view that mathematics should be learned for use as a practical tool, there did not appear to be enough information available on exactly what mathematical knowledge and skills would serve a given purpose. Referring to this problem, Griffiths and Howson (1974) wrote:

> Ignorance concerning what users of mathematics actually need, as distinct from what academic mathematicians think they may need is beginning to be combated by certain surveys. These attempt to find out what mathematics is actually used by graduate engineers and mathematicians in their later employment. (p. 122)

Broad (1972) commented rather tangentially on the same general problem when he wrote:

> Insufficient studies on apprenticeship have been carried out in North America despite the fact apprenticeship as an educational method is both widespread and common. (p. 116)

Nelson and Halfin (1976) stressed the need for direct approaches to curriculum development as opposed to the more frequently used indirect ones:

> Most curriculum developers have taken an indirect or discipline approach in answering these questions . . . All of the indirect approaches provide useful information. However, total reliance on them usually results in a curriculum which is not attuned to the students' present and future needs. (p. 246)

In consideration of the foregoing expressions of opinion, it was concluded that there had been a lack of research on mathematical needs in occupations, on apprenticeship training needs, and also in curriculum development using direct methods.

This study attempted to make a contribution to trade mathematics curriculum development by meeting each of the three challenges enumerated above. The researcher asked journeymen certificated in each of three selected trades to identify the mathematical needs of their occupations in order to provide data that may be used by curriculum developers in the design of high school mathematics courses to meet the needs of students enrolled in high school vocational education programs.

Purpose of the Study

The major purpose of this study was to identify the mathematical skills, knowledges, and understandings that certificated journeymen performing the functions of either supervisors or practicing tradesmen or instructors considered necessary to possess in order that they may be

able to practice their trade in a successful manner. More specifically the supporting objectives of the study were:

1. To identify the mathematical knowledges and skills which were "necessary" for journeymen to possess in order that they may be able to perform successfully in each of the three designated trades of Motor Mechanic, Heavy Duty Mechanic, or Welder.

2. To identify the additional mathematical knowledges and skills which were "desirable" for journeymen to possess in order that they may be able to perform successfully in each of the three designated trades of Motor Mechanic, Heavy Duty Mechanic, or Welder.

3. To devise for each of three trades, a trade mathematics histogram which graphically illustrates the importance of each mathematical skill required in each of the three trades named above and which may be used by designers of curricula for mathematics courses to be offered to students enrolled in the high school vocational education programs of Automotives and Welding whose corresponding trades are Motor Mechanic, Heavy Duty Mechanic and Welder.

Delimitations and Limitations of the Study

The study was delimited to the subject of mathematics and to the designated trades which corresponded to the vocational high school programs in Automotives and Welding. These were three in number and their relationship to vocational high school programs was explained by Alberta Department of Education (1976) as follows:

> Some Vocational High School Programs are similar in scope to the junior periods of some apprenticeship programs. In particular, similarities prevail between . . . Automotives and Motor Mechanic apprenticeship, Automotives and Heavy Duty Mechanic apprenticeship . . . Welding and Welder apprenticeship. (p. 27)

The study was delimited to the designated trades which corresponded to the High School Vocational Programs in Automotives and Welding, namely, Motor Mechanic, Heavy Duty Mechanic, and Welder. These three trades were selected for inclusion in the study because of their correspondence to the vocational education programs in Automotives and Welding which were included in the same group of curricular offerings at St. Joseph Composite High School.

The study was delimited to certificated journeymen functioning in one of three employment categories, namely, "Supervisor", "Journeyman", and "Instructor".

The study was delimited geographically to the City of Edmonton, in the Province of Alberta.

For the purposes of this study, it was assumed that the ability to apply mathematics to problems with unfamiliar elements was of prime importance and also that it was the highest level of outcome necessary to enable journeymen to function successfully in the practice of their particular trade (Bloom, 1956, pp. 112, 125). Since the application level was assumed to incluse the lower levels of knowledge and understanding, the scope of this study has been delimited to the first three levels of the cognitive domain. In this connection, Bloom (1956) stated: "Objectives in one class are likely to make use of and be built on the behaviors found in the preceding classes" (p. 18).

The following limitations were inherent to this study:

1. The study was selective in that restrictions were placed on the eligibility of journeymen for inclusion in the sample.

2. The study was based on the respondents' perceptions which are subject to a variety of distortions as pointed out by Kaplan (1964, pp. 131 - 134).

3. Quota sampling, a non-probability form, was used in the second stage of selection of the "Journeyman" stratum of each sample.

4. The study was limited to the mathematical functions identified by the participants of the study.

Significance of the Study

Vocational high school program curricula, in order to be relevant, must reflect current practice in corresponding occupations or trades, so the curricula of general and academic subjects offered to vocational students must meet their needs in terms of those items of content which are relevant to their particular vocational high school programs. This study presents data which relate to items of content which may be used by designers of mathematics courses offered to students of the high school vocational education programs in Automotives and Welding.

Definitions of Terms

The following definitions are operational and apply to terms as they are employed in the context of the study.

Accelerated Pattern of Apprenticeship

A shortened apprenticeship program which is arranged for eligible graduates of vocational high school programs. This pattern was referred to in Opportunities in Apprenticeship by Alberta Manpower and Labour (1973): "Accelerated patterns of apprenticeship are arranged for graduates of Vocational High School Programs" (p. 3). The mechanics and conditions of eligibility for this pattern were described by Alberta Department of Education (1976) as follows:

> Some Vocational High School Programs are similar in scope to the junior periods of some apprenticeship programs . . . A person who presents to Apprenticeship Authorities of Alberta Advanced Education and Manpower one hundred high school credits, including at least 35 credits in one of the above High School

> Programs (excepting Beauty Culture) and an acceptable application for apprenticeship in the corresponding apprenticeship program, may be granted apprenticeship credit on the following basis: (i) For Building Construction, Electricity, Pipe Trades, Automotives, Auto Body, Sheet Metal, Machine Shop, Electronics - upon recommendation of employer, one year of time credit (3 months shortening of each of four 12-month periods) and First and Second Period Technical credit upon passing the examinations for these periods . . . (iv) For Welding and Food Preparation upon recommendation of employer, one year of time credit (four months shortening of each of three 12-month periods) and First Year Technical Credit upon passing of the First Year examination. (pp. 27 - 28)

Apprenticeship

A period of organized supervised training, both in school and on the job, to prepare an apprentice for achievement of journeyman status. This definition was derived from Canada Department of Labour (1957) which stated:

> Apprenticeship . . . is considered by advocates of this modern concept as meaning a period of organized and supervised training . . . such comprehensive training can only be carried out successfully by a properly organized and regulated system of apprenticeship which combines both school and "on-the-job" training. (p. 7)

Also, Alberta Manpower and Labour (1973) stated:

> Apprenticeship is a learning while earning arrangement. Apprenticeship is a training-on-the-job and trade school training program. Apprenticeship is a certain route to Journeyman status. (p. 1)

Finally, the above definition was supported by British Columbia Department of Labour which stated:

> The term "Apprenticeship" as used today means supervised employment to learn a skilled trade or occupation. A skilled trade consists of two main parts - manual skill and technical knowledge. Manual skill is obtained mainly through experience on the job under the direction of a skilled person engaged in the trade - a tradesman. Technical knowledge is acquired at special training classes. (p. 32)

Apprenticeship Act

For the purpose of this study Nielsen (1973) provided a suitable definition for the term Apprenticeship Act: "An Act passed by the Alberta Legislature in 1944 governing apprenticeship training" (p. 16). This definition is also supported by Canada Department of Labour (1957) which stated: "The present Alberta apprenticeship program came into existence with the passage of the Apprenticeship Act in 1944" (p. 8).

Articulation

An arrangement whereby vocational high school program graduates who meet certain requirements may be admitted to an accelerated pattern of apprenticeship in a corresponding trade. Alberta Manpower and Labour (1973) stated: "Accelerated patterns of apprenticeship are arranged for graduates of Vocational High School Programs." Also, Alberta Department of Education (1976) stated:

> A person who presents to Apprenticeship Authorities of Alberta Advanced Education and Manpower one hundred high school credits, including at least 35 credits in one of the above High School Programs (excepting Beauty Culture) and an acceptable application for apprenticeship in the corresponding apprenticeship program may be granted apprenticeship credits on the following basis. (p. 27)

Automotives

A vocational high school program which corresponds to an apprenticeship in the Motor Mechanic and Heavy Duty Mechanic trades. Alberta Department of Education (1976) stated: "In particular, similarities prevail between . . . Automotives and Motor Mechanic apprenticeship, Automotives and Heavy Duty Mechanic apprenticeship" (p. 27).

Corresponding Trade

A designated trade whose apprenticeship program, in its junior periods, is similar in scope to a given vocational high school program.

Alberta Department of Education (1976) stated:

> Some Vocational High School Programs are similar in scope to some apprenticeship programs . . . and an acceptable application for apprenticeship in the corresponding apprenticeship program. (p. 27)

Designated Trade

A skilled trade which comes under the terms of the Apprenticeship Act. Canada Department of Labour (1957) states:

> The present apprenticeship program started in a modest way in 1945 with the designation of seven skilled trades under the terms of the new Apprenticeship Act. By 1956, there were 15 trades designated under the Act. (p. 9)

Employing Agency

Any business establishment, corporation or institution which employs journeymen.

Heavy Duty Mechanic

A competent craftsman who, through skill and knowledge, is capable of repairing any of the intricate units which constitute modern stationary power units and mobile industrial equipment. This definition was provided by Alberta Advanced Education and Manpower (1973) in its Heavy Duty Mechanic Program booklet (p. 1).

Instructor

A certificated journeyman who instructs in or teaches a particular trade or trade subjects to apprentices or to students enrolled in vocational high school programs of study. The term was used to describe one stratum of each of the three populations sampled in this study.

Journeyman

A person who holds a certificate of proficiency in his trade awarded under the terms of the Tradesmen's Qualification Act (q.v.).

Junior Period

This term referred to the Technical Period in the first year of some apprenticeship programs and to each of the first two years of others. This definition was established by the Alberta Department of Education (1976) which stated:

> Some Vocational High School Programs are similar in scope to the junior periods of some apprenticeship programs . . . and First and Second Period Technical Credit . . . and First Year Technical Credit. (pp. 27 - 28)

Motor Mechanic

A confident craftsman who, through the competent application of his skills and knowledge, has developed the diagnostic and repair abilities required to satisfactorily service the basic as well as the technically sophisticated components of the automotive units being used today. This definition was provided by Alberta Advanced Education and Manpower (1974, p. 1).

Provincial Apprenticeship Board

A five member Board established under the terms of the Apprenticeship Act to advise the Minister of Industries and Labour on all matters connected with the general conditions governing apprentices. In addition to the above, Canada Department of Labour (1957) stated: "The Board consists of five members, one representing industry, one from organized labour, one representing education, one member from the Department of Industries and Labour and a chairman appointed by the government" (pp. 9 - 10).

Related Subject

Any theoretical subject such as science, technology, or mathematics which forms part of or helps the assimilation of the occupation being

taught. This definition was given by International Labour Office in its T. & D. Abstracts (1975, p. 7). It was also supported by Alberta Manpower and Labour (1974, p. 4). Larson (1972) made a distinction between general education related courses and technically related courses. General education was defined by this writer as "basic or fundamental and liberal education" while technically related courses were defined as "Those courses that directly provide knowledge information essential to the performance of the specialty" (pp. 24 - 27).

Supervisor

A certificated journeyman who is a manager, owner-manager, foreman or other type of supervisor who is in daily contact with practicing journeymen in a particular trade.

Technical Period

A free trade school course of four to twelve weeks in each year of apprenticeship. This is the trade school part of the apprenticeship program. It was described in Alberta Manpower and Labour (1973) as follows:

> Apprentices under contract are required and privileged to attend training courses designed for their particular trade. These are short courses of four to twelve weeks in each year of apprenticeship. Fees are not charged for them. (pp. 4 - 5)

Tradesmen's Qualification Act

An Act passed by the Government of Alberta in 1936 establishing the principle of qualifying as a journeyman by the passing of practical tests and examinations and prohibiting unqualified persons from engaging in designated trades. This definition was given by Canada Department of Labour (1957, p. 9).

Vocational High School Program

A three-level (Grades 10, 11, 12) series of courses yielding at least 35 credits in a career field. These are listed by Alberta Department of Education (1976, p. vii - xi) under "Industrial Education".

Vocational Student

For the purposes of this study, any student who is registered in a vocational high school program of study.

Welder

A competent craftsman who, through his skill and knowledge, is capable of fabricating metals by fusion. This definition was furnished by Alberta Advanced Education and Manpower (1973) in its Welder Program booklet (p. 1).

Population and Sampling

The three populations for the study consisted of three discrete groups of certificated journeymen, one from the Motor Mechanic trade, one from the Heavy Duty Mechanic trade, and one from the Welder trade. Each of the three populations listed above was stratified on the basis of the functions performed by the journeymen. The first stratum, called "Supervisors", consisted of certificated journeymen who were managers, owner-managers, or foremen who were in daily contact with practicing journeymen. The second stratum, referred to as "Journeymen", consisted of practicing certificated journeymen who were judged to be successful by their supervisors. The third stratum, labelled "Instructors" for the purposes of this study, consisted of certificated journeymen who were employed as instructors or teachers and who were instructing in or teaching trades or trade subjects to apprentices or to students registered in high school vocational education courses. The populations were

divided into three strata yielding a total of nine subgroups for sampling purposes.

The design of the study called for a two-stage sampling procedure for the "Supervisor" and "Journeyman" strata of each of the three populations. This approach which was referred to by Selltitz, Jahoda, Deutsch, and Cook (1967, p. 534) was chosen for reasons of feasibility and practicability. For the first stage, three lists of employing agencies were compiled, one for the Motor Mechanic trade, one for the Heavy Duty Mechanic trade and one for the Welder trade. Using a simple random sampling procedure without replacement, five employing agencies were selected from each list giving a total of fifteen. D. Raj (1972) explaining this selection procedure stated in part:

> A basic method of sample selection is simple random sampling. In this method each unit of the population has the same probability of being selected in the sample. The selection is usually made with the help of random numbers after the units in the frame have been numbered from 1 to N . . . In case the same number occurs again, the repetition is skipped . . . If repetitions are included, the sample is said to be selected with replacement. (p. 32)

For the second stage of sampling, a quota sampling approach as referred to by Selltitz, Jahoda, Deutsch and Cook (1967, pp. 116 - 120) was used. The service manager, owner-manager or foreman from each of the five employing agencies selected from each trade group was designated a member of the "Supervisor" subsample for his trade category. Each of the 15 "Supervisors" was asked to select from the group of journeymen who worked under his supervision two individuals on the basis of success as a practitioner of his trade and years of experience in the trade. These 30 selected individuals were designated as members of the "Journeymen" subsamples to complete the three samples. The three samples, in their final

form, each consisted of five "Supervisors", ten "Journeymen", and five "Instructors" giving a total of 60 subjects in all for the three samples.

Methodology

The design of this study called for opinion data to be obtained from three categories of certificated journeymen in each of the three skilled trades of Motor Mechanic, Heavy Duty Mechanic and Welder. Stratified samples were drawn from each trade category population of certificated journeymen.

The research instrument for the study was a questionnaire in the form of a mathematical checkoff list similar in structure to the one used by Laws (1966) for his study, Mathematical Expectations of Technicians, (pp. 48 - 51). The questionnaire consisted of 45 mathematical knowledge and skill items developed from a number of sources including Wilson (1952, pp. 28 - 29), Carlton (1953, pp. 8 - 9), Laws (1966, pp. 48 - 51), Smith (1973, pp. 78 - 80), Fitzgerald (1976, pp. 43, 44), as well as a number of textbooks and other trade references. Respondents were asked to rate each of these mathematical knowledge and skill items on a three point Likert-type scale as either "necessary" or "desirable" or "not needed" for the successful practice of the trade they represented. Also included in the questionnaire was a section for remarks and additions by the respondent.

The research instrument for the study was submitted to a specialist in Mathematics Education for the Mathematics Department of The University of Alberta for review and criticism. The instrument was also reviewed by a specialist in instrument design of the Department of Educational Psychology of The University of Alberta.

A pilot study was carried out for the purpose of pointing up any possible errors or inadequacies which might have been present in the re-

search instrument. The pilot study was conducted among a group of nine subjects selected on the basis of one representative for each stratum of the three populations. All but one of the pilot study subjects remained as elements of the populations and were therefore eligible for selection as sample subjects for the main study. The lone exception was a welder who was not a population member by virtue of the fact that his place of business was located outside of the boundaries of the City of Edmonton.

Pilot study participants were contacted by telephone, given a brief explanation of the purpose and method of the study, and informed that they could expect to receive a questionnaire within a short time. The questionnaires were then delivered along with a covering letter and a stampled self-addressed envelope. The responses were analyzed by the researcher and the information thus gathered served as a basis for modifying the research instrument as deemed necessary before it was used in the main study. One area of particular concern was the unavoidable use of mathematical terminology which might have been misinterpreted or not understood by respondents thereby eliciting responses which might be considered invalid.

The modified and corrected instrument was printed and readied for distribution along with a covering letter outlining the purpose and briefly explaining the methodology of the study. For the "Supervisor" and "Journeyman" groups, arrangements were made by the researcher to visit each of the fifteen supervisors of the selected employing agencies for the purpose of delivering the questionnaires and obtaining the names of the subjects selected to complete them. The supervisors were asked for their co-operation in expediting the completion and return of the questionnaires. A follow-up call was made to any supervisors whose

questionnaires had not been received within one week of delivery. In addition to serving as a reminder, this call gave the researcher an opportunity to attempt to resolve any difficulties which respondents might have been experiencing in completing the questionnaire.

For the "Instructor" category, the subjects were contacted by telephone and given a brief outline of the purpose and methodology of the study. They were asked to complete and return the questionnaires which would be forwarded to them along with a stamped self-addressed envelope.

As completed questionnaires were received, responses were tabulated for each item in each of the three trade categories. The frequencies for each response category ("necessary", "desirable", "not needed") were converted into percent proportions of the total number of responses for each questionnaire item. These proportions were then used as a basis for the construction of compound bar histograms to graphically illustrate the respective proportion of each category or response to each questionnaire item. The information thus presented may be used by curriculum designers in the development of mathematics courses for students enrolled in high school vocational programs in Automotives and Welding.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The previous chapter dealt with the need for the study, the purpose of the study, the delimitations and limitations of the study, the significance of the study and definitions of terms used in the study. The chapter also included descriptions of the populations for the study, the sampling procedure used in the study, and the methodology of the study.

This chapter consists of a review of related literature which was undertaken in order to determine the importance of mathematical skills and knowledges as they relate to developing mathematical competencies in the skilled technical trades of Motor Mechanic, Heavy Duty Mechanic and Welder; to determine whether present school mathematics programs meet the needs of students who may choose to pursue a career in one of these trades; and to determine the mathematics content of textbooks and other trade reference works for each of these three selected trades.

Educational literature was found to contain statements which seemed to suggest that learning was dichotomized as to intent into two branches the first being referred to as liberal, general, or academic education and the second being referred to as practical, vocational or occupational education or training. In addition to showing these two facets of education as being in opposition to one another, some educational writers and researchers such as Judkins (1926), Northrop (1955) and the Educational Research Council of Greater Cleveland (1966) have made statements which suggested that the former was inherently more important or valuable than the latter.

A more balanced review of the relation between the liberal and practical arts was presented by writers and researchers such as

Priestly (1947) and Fawcett (1964) who drew attention to the dual nature of mathematics as a computational device on one hand and as a rational structure on the other. Some writers and researchers such as Arnstein (1965) and Larson (1972) emphasized the academic content of occupations or the theoretical foundations of vocational subjects while others such as Kline (1958) suggested that theoretical knowledge has originally developed out of a need to solve practical physical problems. There seems to be general agreement among these writers and researchers on the proposition that most if not virtually all occupations require some knowledges or skills that derive from academic or general education.

Having proceeded on the assumption that occupations did indeed have academic or theoretical knowledge and skill content, it followed that when the teaching of those occupations was undertaken, such teaching would include the academic or general education portion of the knowledges and skills which were deemed to be part of or necessary to the practice of those occupations. In practice, the academic or general education and other theoretical components of occupations have been organized into divisions by discipline and these divisions have been commonly referred to as related subjects. Among courses offered in subjects related to a given trade or occupation one might find such titles as Mathematics, Science, Communication, or Technology. The content of these courses was usually restricted to what was required for teaching a particular occupation and no attempt was made to teach the whole subject. In some cases "core" curricula of related subjects were developed to apply to two or more occupations or trades which had common or overlapping academic or theoretical requirements.

One related subject which figured prominently in the technical trades was mathematics. Writers and researchers including Werremeyer

(1921), Larson (1972) and Smith (1973) have stated that most occupations, especially those of a technical nature, tended to have a considerable requirement for mathematical knowledge and/or skills.

Academic Content of Occupations

Several writers such as Larson (1972) and Rappaport (1976) and researchers such as Smith (1973) and Fitzgerald (1976) have drawn attention to the importance of academic or general education knowledges and skills in most occupations. The United States Office of Education in its 1963 report on vocational education indicated that a lack of adequate training in mathematics and English had been a major problem for high school graduates seeking to enter many occupations and suggested that "everything possible should be done to make these students understand that mathematics and English are a very crucial part of their future vocational success in many fields" (p. 11). In its 1964 report the United States Office of Education again stressed the value of the basic educational skills as a prerequisite for vocational education when it stated:

> Vocational Education can be effective only when the student has acquired the basic educational skills. Reading, oral expression, written expression, and numerical computation are important for all but the most rudimentary forms of employment. (p. 221)

Arnstein (1965) drew attention to the academic content of many occupations and stressed the fact that though the physical aspects of an occupation may change, the academic content is more likely to remain the same. In order to illustrate his point, Arnstein used the following example:

> The panel seems to overlook to a great extent the increasingly abstract and academic content of many modern occupations. The bricklayer, if he is to remain employed, will continue to read blueprints

> and diagrams although he may no longer work with bricks. Plumbers have learned to use plastic pipes instead of the traditional metal pipes, but they continue to need skills in numbers, in reading instructions, and for communicating with their colleagues. (p. 61)

Johnson (1971) having consulted with representatives from business and industry reported that there had not been sufficient emphasis placed on preparation for learning technical skills. This researcher wrote "schools should tell students that they need to have a good foundation in math and physics before they can learn technical subjects" (p. 60). Larson (1972) defined general education as "basic or fundamental education and liberal education" and stressed its necessity for occupational education when he wrote:

> Certainly the ability to read and interpret the written word as well as the application of some mathematics is necessary for most, if not all, fields of vocational and technical education even at the most primitive stages and beginning levels as applied in the twentieth century. (p. 24)

Mathematical Requirements of Occupations

The literature on related subjects was found to contain numerous references to the mathematical requirements of various occupations including skilled trades. For example, British Columbia Department of Labour listed mathematics as part of the course content in 13 out of 22 trade apprenticeship programs listed and implied mathematical content in five more of these programs (pp. 7 - 27).

Kadushin (1942) pointed out that all kinds of jobs common in industry had higher mathematical contents than generally believed. This writer also stated that productivity suffered from the fact that workers at all levels from engineering work through the skilled trades and down to the unskilled production jobs were deficient in mathematical compe-

tencies that would make them able to work more efficiently (pp. 260 - 261).

Laws (1966) in a study whose purpose was to determine the mathematical skills needed by technicians employed in Michigan industries found a high level of need for computational skills normally downplayed in modern mathematics programs and found no need for natural logarithms, number theory, probability, set theory, inequalities, methods of proof and reasoning, calculus, and many other items which tended to form an important part of these programs. Laws also made the point that while neglecting mathematical skills deprives the student, it is possible to err in the direction of excess:

> If the student acquires too little mathematical skill he will not be able to function as a technician. But, if the mathematical requirements are unrealistic, many prospective technical workers will fail to qualify and the surplus of unskilled workers and shortage of skilled workers will continue. (p. 19)

The United States Office of Education's Diesel Servicing Curriculum (1969) included a section entitled "Basic Mathematics" which called for 48 hours of classroom instruction in mathematics. The course description of the Diesel Servicing Curriculum provided the following summary for basic mathematics:

> Basic Mathematics - covering such topics as whole numbers, fractions, decimals, and percentages - play an important part in making many of the calculations necessary in the Diesel service area. Precise measurements calling for close tolerances can be made only with a thorough understanding of the use of measuring devices. A knowledge of certain formulas as they apply to volumes, efficiency of engine operation, calculating horsepower, and the like are covered in this course. (p. 19)

Larson (1972) described mathematics as a "tool subject" and stated

that as such, it performed two basic functions:

> First, it may be used as a method in teaching principles of science and technology. Secondly, it is necessary for calculations and computations essential for operations and jobs to be performed in the shop and laboratory. (p. 38)

Smith (1973) in a study which was conducted with workers and supervisors in a variety of geographical areas in the Province of Saskatchewan and whose purpose was to identify generic skill components of tasks and subtasks carried out in 27 different occupations found a high frequency of basic mathematical skill requirements in virtually all of the occupations analyzed (Appendix 3, pp. 1 - 120).

A. Fitzgerald (1976) of the University of Birmingham (England) School of Education conducted an investigation into the mathematical requirements of an Engineering Company for its beginning craft and technician apprentices. Information was obtained from students' notebooks and from discussions with training officers, and the results were verified by visits to other companies. From this information this researcher compiled a catalogue of mathematical items taught to beginning craft and technician apprentices by engineering companies. This list included metric and imperial units, ability to draw neat diagrams, parallel lines and symmetry, measurement of angles, commonly used fractions, manipulation of formulas expressed as fractions, simple decimals, conversion of vulgar fractions to decimals, the four rules applied to whole numbers, vulgar fractions and decimals, estimates and approximations of simple calculations, order of operations, standard form and powers of ten, simple two and three dimensional shapes, volumes of simple solids, percentage calculations, appreciation of tolerance, knowledge of and application of formulae, manipulation and substitution in formulae involving vulgar fractions and decimals, an understanding of

the derivation of formulae, appreciation of ratio, Ohms' Law, simple graphs, interpolation on a scale, positive and negative values, ideas of error and of the relative importance of an error. Fitzgerald explained that while the apprentice was "not expected to have met all items while at school, or necessarily to be very competent in all those they have met", considerable competence was desirable in many of the items such as calculations based on vulgar fractions and decimals and equations containing one unknown which are likely to be met by the apprentice during the first few weeks of work. It was not necessarily expected of pupils that they should be familiar with applications of mathematical ideas to workshop practice (pp. 43 - 44).

Mathematics Programs: Evaluations and Comments.

Kline (1958) emphasized the fact that curriculum designers in mathematics were moving ever further from reality when he wrote:

> The traditional curriculum is already meaningless, and by heading for abstract mathematics the modernists are moving farther away from reality. To teach pure mathematics apart from physical problems is to lose the gold and keep the iron in the ore of real mathematics. The meaning of mathematics, if I may be somewhat paradoxical is not in mathematics. (p. 424)

It is noteworthy that Kline not only faulted the modern mathematics curriculum, but also found the traditional one wanting. Also, Kline addressed the problem of motivation in mathematics instruction and made the point that "for young people at least, the motivation for a mathematical idea or method is not a more advanced mathematical idea or method". This researcher argued that "we must motivate each topic with a genuine problem and show that the mathematics does something to solve that problem" (p. 426). Elaborating on this point, Kline wrote:

> In view of the actual motivation for the creation of

> mathematics, the motivation we can use is the solution of simple, genuine, and basic physical problems. Of course, the social sciences, art, and music also provide good problems. (p. 426)

Travers (1965) in a study whose main purpose was to determine whether students exhibited preferences for solving mathematics problems based on some situations rather than others found that the study sample preferred solving mathematical problems that were directed at the social-economic, the mechanical-scientific, and the abstract problem situations in that rank order. This finding applied to both the high and low achievement levels within the sample although the high achievers selected the abstract problem-solving situations more frequently than did the low achievers (pp. 7161 - 7162).

Large school enrollments made possible a range of offerings within a subject area which accommodated varying interest and/or ability levels among the student population. In practice, this process involved grouping of students within a subject area into two or three levels and was generally referred to as "streaming". In its rationale for revision of the high school mathematics curriculum, the Alberta Department of Education (1970) made specific reference to "three streams of mathematics" (p. 2). Also, the Alberta Department of Education (1971) stated: "To deal with differences in ability, interest, and motivation, the curriculum in mathematics consists of three programs, each of which represents good mathematics" (p. 1).

Johnson (1971) suggested a remedy for a perceived educational weakness about which representatives of business and industry were concerned:

> Schools should be more careful to train young people in precision [italicized in original]. For many, an approximation of the right form seems adequate.

> Some of the instructional methods seem to tolerate haphazard or sloppy responses. Industry must [italicized in original] have accuracy. (p. 60)

Although streaming made possible program offerings suited to a broader range of student abilities or interests, its implementation has not been an unqualified success. Bowen (1966) referred to a common attitude on the part of educators toward less able students which results in their being shunted into applied mathematics courses. "We proclaim a value system which says that applied mathematics is for dullards and assume that the better students will learn applications by some mysterious osmosis" (p. 542).

Mueller (1967) described a situation occurring in higher education wherein the neglect of mathematics applications by mathematics departments led to the development and teaching of utilitarian mathematics courses by other divisions of universities in order to meet the specific needs of their own programs. Mueller also thought the signs were ominous that a similar stalemate was developing at the school-mathematics level, expecially since the resurgence of vocational education programs whose students require mathematics "of a vastly different sort from what is usually proposed for the liberal arts student" (p. 705).

Professor F. M. Arscott in his foreward to Rektorys' Survey of Applicable Mathematics (1969) commented on recent progress in mathematics and stated: "This coincidence of an explosion of mathematical activity with greatly enlarged scope for its application is, unhappily, overshadowed by a communication barrier. Between those who have mathematical knowledge and those who wish to use it, there lies a great gulf" (p. 21). Arscott proposed that abstract mathematicians might be made aware of "intriguing and challenging problems waiting for them in other fields" but he also advised the reader that "mathematicians are not easily

tempted from their ivory towers" (p. 21).

Mallinson (1974) stated that doubts had begun to surface some time previously about the value of the new mathematics programs, especially as to their usefulness in the solution of contemporary practical problems:

> It was, of course, evident as far back as 1967 that the gravy train was beginning to run out of gravy. Concerns were being expressed about the applicability of the new program to national concerns, and particularly concerning their contribution to the knowledge of students. Students learned to inquire about intangibles and nonsense objects in science courses, and learned about sets, rings and groups in mathematics but could not make change for a hot dog. Unfortunately, the programs did little to help the students understand environmental problems, the inpending energy crises, the problems of drugs and alcohol, and the need for marketable knowledge and skills. (p. 558)

The Secondary School Mathematics Ad Hoc Committee of Alberta (1975) in a survey of high school mathematics found that 78 percent of respondents thought that time allotted to problem-solving was inadequate in current programs (p. 18). Among conclusions reported by the committee were that "both conceptually and methodologically the current high school mathematics program is formal rather than intuitive or related to applications", and that "there is a sore lack of emphasis on problem-solving" (p. 30).

Peterson and Peterson (1975) wrote that teachers often have a disdain for teaching the non-academic, vocational, and service courses. The cause of this problem was likely to be "fear of the unknown" due to the fact that few mathematics teachers had worked in business or industry where they used mathematics. Thus, mathematics teachers were unable to communicate the uses of mathematics to their students because they "do not know how to apply their mathematical knowledge except to the study

of mathematics or science" (pp. 84 - 85).

Farnsworth (1976) reporting on a seminar organized to discuss "Modern Mathematics and Further Education for Industry, Trade and Commerce" stated that "the industrial representative - senior people in engineering, insurance, printing, and the Post Office - strongly criticized the basic mathematical ability of young school leavers". The author enumerated three points regarding the possible origins of mathematical difficulties in the schools and went on to suggest that "some attention must be directed at these areas, if young school leavers are to be better equipped to meet the basic mathematical requirements of their employment, and to cope with the rigorous demands of vocational courses in further education" (p. 26).

Rappoport (1976) described three groups of people of varying ability levels which made up society. The first group which included 10 to 15 percent of the population was made up of the "innovative and creative people who are really the great minds of society". The second group which included 15 to 25 percent of the population was made up of "great minds who, though not creators, are capable of understanding and appreciating the work of the creative people" (p. 344). He went on to describe the third group and their mathematical needs:

> The third group of people is the 60 percent who compose the rest of society. They are the bulwark of society, the ones who make society function. They are the people who work in factories, on the farm, in shops and stores, and perform the duties of a well-run society . . . The 60 percent of children who are in the third group do not need to learn mathematics [italiciaed in original], certainly not as an abstract structured system. These children do need to learn the basic arithmetic skills in order to function effectively in society. (p. 344)

Pike (1976) in a study whose purpose was to evaluate the strength

of feeling among college lecturers that the implementation of modern mathematics in the schools had led to an apparent decline in the standard of those mathematical skills needed for vocational ends, found among other things that little use was made of "modern" topics in Further Education. Also, respondents' free comments showed that "there is a strong feeling in Further Education that a change of emphasis is required in the teaching of 'modern maths' in the schools". It was thought that more attention should be paid to manipulative skills with less concentration on some of the more abstract topics present on "modern" syllabuses (p. 27).

Reys (1976) reported the results of an extensive study of the computational skills of young adults as applied to the solution of mathematical problems which are commonly encountered in everyday life. The subjects in this study ranged in age from 26 to 35 years and included all educational levels from "less than high school" to "college graduate". It was found that 30 percent of young adults, including 7 percent of the college graduates could not answer a problem involving the fundamental base-100 concept of percentage. Only about half of the subjects were able to calculate wages correctly from a time sheet which gave working times and the hourly rate. In a problem involving income tax, just over one half of young adults were able to determine the correct figure from a tax table. Only 16 percent of young adults were able to balance a cheque book though 87 percent of them had chequing accounts of their own. Even among college graduates, nearly all of whom had chequing accounts, fewer then one third were able to complete the chequebook exercise correctly (pp. 258 - 259).

Another accusation of failure in the schools appeared in the Newsweek article titled "The Valedictorian" (Sept. 6, 1976). This

article described the plight of a student who worked hard all through school and finally graduated as valedictorian. This graduate's hopes of attending George Washington University were dashed when he placed in the lowest 13 percent in verbal ability and in the lowest two percent in mathematics on the Scholastic Aptitude Test. The dean of admissions at George Washington University was quoted as saying, "My feeling is that a kid like this has been conned. He's been deluded into thinking he's gotten an education . . . Sometimes I think averages are pulled out of the air". The article's concluding statements said something about what is expected of the schools and raised doubts as to how well this expectation was being fulfilled:

> How does it happen that a valedictorian can barely read or compute as measured by standardized tests? How well are schools preparing students for college? (p. 52)

Purposes and Objectives of Mathematics Instruction

Werremeyer (1921), sounded a warning of the dangers of neglecting skill acquisition as an objective of mathematics education when he stated in part:

> With the lack of constructive supervision [italics in original], there is great danger of teachers becoming so highly enthused about the multiplicity of informational subjects that are now being advocated for the curriculum in mathematics that the pupils may be left woefully weak in arithmetic skill, the very point that needs most careful attention, because it is upon this point that schools meet adverse criticisms on every hand in the business and professional world. (p. 255)

The criticism made by Werremeyer in 1921 was similar to that made by J. L. Chesney (1976) who complained that education was not doing enough to prepare students for a productive role in society. D. E. Smith (1921) thought that the most encouraging feature of the recent advance in the

teaching of mathematics was the possibility of a new and stimulating course in the subject: "it allows mathematics to relate itself to the interests and apparent needs of young people instead of being presented as a purely abstract science" (p. 124). The foregoing seems to suggest that the problem of excessive abstraction and lack of application in mathematics education are not of recent origin but in fact have been with us for quite some time.

Judkins (1926) stated that teachers of mathematics can be most effective by making the primary aim "the study of the subject for its own sake, for the pleasure found in its pursuit". In support of this view, she cited a 1905 study conducted among mathematicians by an unnamed French mathematical journal which reported that "their interest was due to a desire to develop the subject for its own sake rather than for its applications" (p. 82).

Rothe (1942) reminded mathematics teachers that 75 percent of their students would not go to college and should be equipped with skills that would be useful to them in trade and industrial jobs (p. 70).

Priestly (1947) in an article entitled "Conflict Between Theoretical and Computational Mathematics" drew attention to a distinction which existed between mathematics as a logical, symbolic expression of functional relationships or mathematics as a device for computational purposes. While the theoretical mathematician found computation distasteful, the mathematics teacher usually found it difficult to make the transfer from theoretical to computational mathematics because of lack of experience in the latter. Thus neither mathematicians nor mathematics teachers are capable of making the transfer from theoretical to computational mathematics for the average student (p. 24).

More recently, Northrop (1955) expressed the opinion that secondary school mathematics was becoming less and less relevant to modern mathematics because it was slow to respond to new discoveries in the field of mathematics (p. 386).

Smith, Stanley and Shores (1957) commenting on studies concerning the usefulness of subject matter reported that in most cases, utility was defined in terms of frequency of use: "those items of subject matter most often used by adults being considered the most useful and, hence, the most desirable as curriculum content". They cited one example where school children collected arithmetic problems encountered by their parents over a two week period (p. 135).

Fawcett (1964) referred to the "two faces" of mathematics and stated in part: "on the one hand, mathematics serves the needs of man as he tries to understand and manipulate his environment while, on the other hand, it deals with a body of concepts and principles as they slowly evolve into a noble, rational structure" (pp. 451 - 452).

The Educational Research Council of Greater Cleveland (1965) stated that mathematics education had two parallel objectives at the seventh - grade level:

> The first objective is a clear understanding of the structural interrelationships of numbers . . . The second objective is skillful and rapid computation. The first objective is a thinking process and cannot be hurried. The second objective is a mechanical process and should be practiced until the pupil attains accuracy. (p. 182)

Mueller, (1967) criticized the lack of specificity typical of mathematics objectives as follows:

> You didn't have to listen very long to realize how vulnerable we are in mathematics education. We, the missionaries and distributors of a product that knows no peer in precision and succinctness, do indeed state our objectives - our goals - in the

> vaguest sort of rhetoric, couched in soaring platitudes, rich in fervor and zeal, but utterly devoid of any measurable criteria. (p. 705)

Mueller suggested that the phrasing of mathematics program objectives in a vague manner creates difficulties in teaching and makes accurate evaluation impossible (p. 705).

J. A. Rhodes (1969), Governor of the State of Ohio, when he spoke of the problem of the irrelevancy of present school mathematics programs to societal needs, cited the example of a carpenter who, though he had never heard of the Pythagorean Theorem, could make practical use of it in his work. Rhodes suggested that mathematics and science should be taught in relation to an occupation and real activities in which theory could be put to work (p. 25).

Griffiths and Howson (1974) quoted Professor John Perry, a former physics teacher at Clifton College as saying in 1901: "The study of mathematics began because it was useful, continues because it is useful, and is valuable to the world because of the usefulness of its results, while the mathematicians, who determine what the teacher shall do, hold that the subject should be studied for its own sake" (p. 17).

Brown and Kinney (1975) referred to Grade nine mathematics and suggested a re-examination of purposes when they wrote:

> The study of mathematical application is justified not only to support the study of mathematics as a science but also as a major purpose. It goes without saying that personal efficiency of the individual is enhanced as he learns more mathematics. That is, the range of problems he can attack is greatly increased. (p. 616)

The secondary School Mathematics Ad Hoc Committee of Alberta (1975) conducted a survey of senior high school mathematics and reported that "The major concensus derived from the comments on the objectives is that: a) the applicability of mathematics to practical real life

problems should be emphasized; b) mathematics should be made more enjoyable" (p. 2).

Kapur (1976) stated that 90 percent of today's mathematics could be given up without affecting its applicability and reminded readers that "As mathematics becomes more and more abstract and moves further and further away from the sources from which the abstractions arise, its relevance begins to be questioned". Kapur went on to explain how the relevancy of mathematics continued to be threatened when he wrote:

> Mathematics has always been a relevant component of human culture and a large number of mathematical scientists are trying to keep it so, but there are others who consider the question of relevance irrelevant. Fortunately, the latter have never got the upper hand, but the former group of mathematicians and the society which supports mathematics must always be vigilant. (p. 171)

J. L. Chesney, (1976) general manager of the Edmonton Chamber of Commerce writing in Business Reporter, expressed views which might be considered typical of those which emanate from business and industry groups via their representatives:

> In looking over a recent publication by the Department of Education, I find that the goals of education certainly leave a lot to be desired by the business community. They are basically how to be a good citizen, how to understand the changes in the world, how to communicate, develop skills in communication, how to organize, analyze and use information, how to get along with others, learn about the use of leisure time, how to understand health and fitness and to appreciate the culture and beauty of the world and develop basic and special knowledge competencies. Now the one that really turns us on, of course, is the final one which is develop basic and special knowledge competencies. (p. 5)

Having found the goals of education inappropriate for the business community, Chesney proceeded to describe the criterion by which he judged the validity of the schools' curriculum:

> If a student is going to spend 12 years in elementary,

> junior and high school and then go on to further education at the University of Alberta it certainly seems realistic that after giving up and devoting that kind of time to learning they should certainly come out with the skills of the economic system that they are going to be asked to make a living in . . . It just seems realistic to me to suggest to the education system of our province that when they graduate a student, that can immediately go out into the work force into whatever field they choose and be productive in that work force, and to help and create and generate the economy that is needed to move this country ahead. (p. 5)

A case for stating instructional objectives in vague and general terms was presented by Zahorik (1976) when he wrote: "General objectives develop democratic ideals because they permit the kinds of freedom that a democracy espouses" (p. 417).

Opinions of Mathematics Educators

Harding (1968) in a study entitled "The Objectives of Mathematics Education in Secondary School as Perceived by Various Concerned Groups" found a marked divergence between the opinions of teachers and those of other adult groups on the importance of practical arithmetic skills. This researcher reported that the objective of becoming adept at applying arithmetic to problems of business and personal finance "was rated much higher by every other adult group than by mathematics educators" (p. 117).

Oregon State Department of Education (1975) alluded to a problem of divergence of opinion between teachers and users of mathematics when it made the following statement in its Oregon Vo-Tech Mathematics Project Final Report:

> Consider more extensive use of industry people to assure relevance of problem sets. (Make sure problems reflect actual needs of industry rather than what instructors perceive those needs to be). (p. 31)

Olson and Freeman (1976) conducted a study whose purpose was to

determine which objectives for junior high school mathematics were considered most important by each of four interested groups. Teachers, parents, students, and professors of education were asked to rank, in order of perceived importance, fifteen objectives obtained from a search of related literature. These researchers found that the three objectives perceived as most important and selected in the same order by both students and parents were, first, "To develop mathematics skills used in daily living, i.e., be able to use mathematics in business and personal finance e.g., insurance, taxes, discount, etc.", second, "To be able to add, subtract, multiply, divide, and to solve equations correctly in arithmetic and algebra", and third, "to acquire the process skills required in obtaining mathematical knowledge, e.g., methods of reading, finding information, the way of thinking, and using the knowledge" (pp. 53 - 54). Olson and Freeman also reported that teachers, parents, and students considered practical mathematical skills to be more important than the structural properties of mathematics, while professors of education considered the structural properties to be more important (p. 57).

Mathematics Objectives in Alberta

Worth (1964) commenting on curriculum changes that were then taking place stated that increased use of the subject matter criterion of significance to an organized field of knowledge had been receiving strong support. This authority cited the new elementary mathematics program as an example of evidence that the emphasis on structure was beginning to make itself felt in Alberta (p. 7).

The high school mathematics curriculum underwent extensive changes after the revision of 1970 (Alberta Department of Education, 1970) and it was thought advisable to examine and compare the contents of stated objectives for high school mathematics programs both before and after the

revision. Senior high school mathematics curriculum guides for 1959, 1963 and 1971 were selected for this purpose. It was found that but for a few exceptions the content of the stated program objectives was almost identical in all three guides. Among the exceptions, the objective "to demonstrate the role of mathematics in the development of occupational skills" was included in the two earlier curriculum guides (Alberta Department of Education, 1959, 1963, p. 4) but was omitted in the latest (Alberta Department of Education, 1971, p. 3). The 1971 curriculum guide did, however, include two items not found in the earlier editions, namely, "to consider the nature of proof as represented by various reasoning modes", and, "to develop an understanding of the main underlying ideas that make up the structure of mathematics" (p. 3).

Review of Textbooks and Other Trade Reference Works

Textbooks and other trade reference works figure prominently in apprenticeship and high school vocational education courses and for this reason it was thought that they might provide pertinent information about the mathematical knowledges and skills needed by journeymen for the successful practice of each of the three selected skilled trades of Motor Mechanic, Heavy Duty Mechanic, and Welder. Because of the special relationship wich was presumed to exist between these reference works and the apprenticeship and high school vocational education programs in which they were used, it was decided to group them under a separate heading within the review of related literature.

Three textbooks or other trade references were reviewed for each of the three selected skilled trades named above and the mathematical knowledge and skill components included in either the expository material or in the review questions and problems provided at the end of each

chapter were tabulated under the same headings as were employed in the research instrument for this study. For the purpose of this review, no special significance was attached to the number of occurrences of any particular mathematical knowledge or skill item found in any one reference work.

Textbooks for the Motor Mechanic Trade

Stockel (1974) in a textbook entitled Auto Mechanics Fundamentals included basic mathematical operations (i.e., addition, subtraction, multiplication, and/or division) with whole numbers (pp. 193, 211, 363), fractions (pp. 197, 199), English weights and measures (pp. 85, 211, 298), measuring with a micrometer (pp. 439, 444), reading gauges (p. 198), ratio and proportion (pp. 199, 212, 225), graph interpretation (pp. 141, 147, 307), application of formulae (pp. 193 - 197), parallelism (p. 320), measuring and producing angles (p. 426), calculating area and volume of cylinder (p. 197). Review questions were included at the end of each of 21 chapters but these consisted mostly of recall items which did not require the application of mathematical skills. For example, a chapter on engine tests and measurements included several formulae and demonstrated their application (pp. 193 - 197), but the review questions did not call for any mathematical skills beyond recalling four of these formulae (p. 199). Metric weights and measures and conversions were referred to only in tables at the end of the textbook (pp. 453 - 459).

Crouse (1975) in a textbook entitled Automotive Mechanics included basic mathematical operations with whole numbers (pp. 360, 418, 459, 512), fractions (p. 136), decimals (pp. 49, 257, 259), English weights and measures (pp. 49, 136, 144, 155), metric weights and measures (pp.

60, 133, 136), conversions (pp. 54, 60), measurement with rule (pp. 50, 373, 476), measurement with micrometer (pp. 51, 410), reading gauges (pp. 256, 260, 291), ratio and proportion (pp. 137, 458, 506), ratio and proportion problems (p. 473), use of tables (pp. 141, 617), signed numbers (p. 525), interpreting graphs (pp. 140, 141, 147, 307), application of formulae (pp. 134, 136), identifying geometric figures (p. 528), measuring angles (pp. 360, 545), and adjusting or laying out angles (pp. 315, 391, 421, 545). References were made using percent (p. 138), but no problems or solutions using percent were included. Conversion tables were located at the back of the book (pp. 633 - 635) and virtually no mathematical skills were included in the review questions at the end of each chapter.

Nash and Banitz (1973) in their textbook entitled Automotive Technology included basic mathematical operations with whole numbers and decimals (pp. 224, 419, 424), percent problems (p. 224), English weights and measures (pp. 21, 84), metric measures (p. 210), measuring with a micrometer (p. 18), reading gauges (pp. 197, 259, 260, 264), ratio and proportion (pp. 126, 129), ratio and proportion problems (pp. 84, 224), using tables (p. 327), scientific notation (p. 208), signed numbers (p. 64), interpreting graphs (pp. 79, 312, 322, 279), application of formulae (pp. 221 - 224, 411), measurement of angles (p. 218), calculating volume of a cylinder (pp. 220, 224). This textbook differed from the others in this group in that the chapter review questions tended to include more problems requiring mathematical skills for their solution. For example, of the ten review questions at the end of chapter 26, four were of this type (p. 224).

In summary, the three Motor Mechanic Trade textbooks reviewed included basic mathematical operations with whole numbers, common

fractions, decimals, percent, and signed numbers, English and metric weights and measures, conversions, measurement with rule and micrometer, reading gauges, knowledge of ratio and proportion, solving ratio and proportion problems, using tables, scientific notation, graph interpretation, application of formulae, measuring and laying out or adjusting angles, and calculating area and volume of a cylinder.

Heavy Duty (Diesel) Mechanic Trade Reference Works

United States Office of Education (1969) in its Diesel Servicing Curriculum included basic mathematical operations with whole numbers, fractions and percent (p. 19), conversion of common fractions to decimals (p. 19), percent problems and English and metric weights and measures (p. 19), reading gauges (pp. 8, 12, 19), ratio and proportion problems, powers of numbers, square roots, graph interpretation, application of formulae, measurement of angles, and calculation of areas and volumes (p. 19).

Black (1966) in Audel's Diesel Engine Manual included basic mathematical operations with whole numbers (pp. 20, 254), fractions (p. 20), decimals (pp. 241, 254), English weights and measures (pp. 17, 20), metric weights and measures (pp. 18, 197), conversions (p. 19), estimating measurements (p. 347), reading gauges (p. 202), ratio and proportion problems (pp. 265 - 268), powers of numbers (p. 272), use of tables (p. 91), graph interpretation (pp. 31, 251), application of formulae (pp. 20, 90, 247, 257, 259), measurement of angles (p. 232) and volume of cylinder (p. 269). The book also contained a section devoted to tables including one giving millimeter equivalents of fractional inch measurements.

Kates (1965) in Diesel and High Compression Gas Engine Fundamentals included basic mathematical operations with whole numbers (pp. 67, 69,

70), fractions (pp. 85, 113), decimals (pp. 61, 70, 347), percent problems (pp. 115, 116, 311), English weights and measures (pp. 62, 63, 70, 253), ratio and proportion problems (pp. 9, 120), powers of numbers (pp. 61, 70), graph interpretation (pp. 106, 131 - 134), application of formulae (pp. 62 - 65, 72), cancellation (pp. 65, 70), measuring angles (p. 63), areas of rectangles and circle (pp. 61 - 62) and calculation of volumes (pp. 62, 78).

Included in the three Heavy Duty (Diesel) Mechanic trade reference works reviewed here were basic mathematical operations with whole numbers, fractions, decimals and percent, English and metric weights and measures, conversions, reading gauges, ratio and proportion problems, finding powers of numbers and square roots, graph interpretation, application of formulae, cancellation, measurement of angles, finding areas of rectangles and circles, and calculation of volumes of cylinders and rectangular solids.

Reference Works for the Welder Trade

Kennedy (1972) in his thesis titled The Development of a Handbook for Welding Theory included basic mathematical operations with whole numbers (p. 16), decimals or percent (pp. 72, 82, 85, 97, 106), English weights and measures (pp. 55, 56, 85, 86, 90, 122), measuring with rule (pp. 54, 56, 129, 151), graph interpretation (p. 80), laying out angles (pp. 54, 56, 129, 151). The work makes numerous references to fractional measurements used in discribing materials such as welding rod diameters, metal stock thicknesses, dimensions of metal pieces.

Pender (1968) in a textbook entitled Welding included basic mathematical operations with fractions (pp. 28, 124), decimals or percent, conversions and percent calculations (p. 124), English weights and

measures (pp. 23, 25), measuring with rule (pp. 39, 42, 45, 50, 57, 75), estimating measurements (pp. 26, 27, 38, 80), reading gauges (p. 28), use of tables (pp. 45, 80), laying out or adjusting angles (pp. 49, 56, 58, 129).

Masson (1967) in a textbook entitled Welding Theory and Practice included basic mathematical operations with whole numbers (p. 57), fractions (pp. 41, 57), decimal or percent (pp. 15, 49, 52, 57), conversions (p. 57), percent calculations (p. 49), English weights and measures (pp. 1, 29, 40), metric weights and measures (p. 21), measuring with rule (pp. 29, 38, 41, 70, 73 - 75), estimating measurements (pp. 18, 19, 41, 72), reading gauges (pp. 17 - 19), ratio and proportion problems (p. 57), use of tables (pp. 46, 49, 62, 65), signed numbers (pp. 3, 4), measurement of angles (p. 39), laying out or adjustment of angles (pp. 38, 43, 70, 73).

In summary, the three reference works for the Welder trade reviewed here included basic mathematical operations with whole numbers, common fractions, decimals and signed numbers, conversions of common fractions to decimals, percent calculations, English and metric weights and measures, estimating measurements, measuring with a rule, reading gauges, solving ratio and proportion problems, use of tables, graph interpretation, and measuring and laying out angles.

Summary of Reference Works for Three Trades

It was found that the three trades of Motor Mechanic, Heavy Duty Mechanic, and Welder shared a number of mathematical competency requirements as indicated by textbooks and other trade reference works. These shared mathematical competency requirements included basic operations with whole numbers and fractions, knowledge of common English and metric weights and measures, solving ratio and proportion problems, graph interpretation and measuring angles.

Some mathematical competencies were shared by two of the three trades being studied here. Reference works for the Motor Mechanics and Heavy Duty Mechanic trades indicated a common need for basic operations with decimals and percent, conversions of English and metric weights and measures, application of formulae and finding area and volume of cylinders. Motor mechanics and welders shared a need for measurements with rule and micrometer, use of mathematical tables, basic operations with signed numbers and for laying out and adjusting angles. No mathematical competencies common only to the Heavy Duty or Welder trades were indicated.

Some mathematical competencies were found to be indicated for only one of the skilled trades being studied here. Motor mechanics were found to need a knowledge of scientific notation and measuring with a micrometer. Heavy Duty mechanics needed competency in finding powers of numbers, calculating square root, cancellation, calculating area of square or rectangle, calculating circumference or area of a circle, and finding area and/or volume of rectangular solids. No mathematical competencies were found to be needed by welders to the exclusion of the other two trades being studied here.

In conclusion, it was found that the textbooks and other trade reference works for the three trades of Motor Mechanic, Heavy Duty Mechanic and Welder indicated considerable similarity of mathematical functions among the three trades.

Summary of the Review of Related Literature

This review of related literature dealt with the academic foundation and content of occupations and the mathematical requirements of the skilled trades. Comments on mathematics programs and evaluations of them were examined as were purposes of mathematics and the objectives of mathematics instruction. A review of textbooks and other trade reference works completed the chapter.

CHAPTER III

DESIGN OF THE STUDY

The previous chapter consisted of a review of related literature which dealt with the academic foundation and content of occupations in general and the mathematical requirements of the three selected trades of Motor Mechanic, Heavy Duty Mechanic and Welder. Comments on mathematics education and evaluations of mathematics programs were reviewed as were purposes of mathematics and stated objectives of mathematics instruction. A number of textbooks and other trade reference works were analyzed for their mathematical content.

This chapter includes descriptions of the population and the sampling procedure for the study. The chapter also deals with the design of the research instrument, the execution of the pilot study and the distribution of the research instruments and concludes with the tabulation of data.

Description of the Populations

The populations for this study included three discrete groups of certificated journeymen. One population included journeymen from the Motor Mechanic trade; the second population was made up of journeymen from the Heavy Duty Mechanic trade; the third population was comprised of journeymen from the Welder trade. Each of these three populations was stratified as to the function performed by the journeymen. These functions were placed into the following three groups: Supervisors; Journeymen; Instructors. The Supervisor group consisted of certificated journeymen who were managers, owner-managers, or foremen who were in daily contact with practicing journeymen in one of the three trades involved in the study. The Journeymen group of each of the three

populations consisted of practicing certificated journeymen who were judged to be successful by their supervisors. The third group consisted of Instructors who, for the purposes of this study, were certificated journeymen who were instructing in or teaching trades or trade subjects to apprentices or to students enrolled in vocational education programs of study at the high school level.

Each of the three populations was stratified into three groups which gave a total of nine subgroups for sampling purposes.

Sampling Procedure

The design of the study called for a two-stage sampling procedure for the "Supervisor" and "Journeyman" strata of each of the three populations, namely, Motor Mechanic, Heavy Duty Mechanic, and Welders. This approach which was referred to by Selltitz, Jahoda, Deutsch, and Cook (1967, p. 534) was decided upon for reasons of feasibility and practicability.

For the first stage of the sampling process three lists of employing agencies were compiled, one for each trade group. The first list consisted of 41 employing agencies which employed journeymen motor mechanics. The second list included 28 employing agencies such as Diesel and heavy duty shops which employed journeymen heavy duty mechanics. The third list consisted of 103 employing agencies such as welding and fabricating shops which employed journeymen welders. Each of these lists of employing agencies was compiled from information obtained from Edmonton and Vicinity Yellow Pages by Edmonton Telephones, 1976. Using a simple random sampling procedure without replacement, five employing agencies were selected from each list giving a total of fifteen. The service manager or other supervisor from each selected

employing agency was then contacted by telephone, given a brief outline of the purpose and method of the study and asked if he wanted to cooperate in the study along with two successful journeymen of his choice who were working under his supervision. At the same time, an appointment was arranged with the supervisor so that questionnaires could be delivered and further explanations given relating to the completion and return of the questionnaires. At the time the questionnaires were delivered it was suggested to the supervisors that they might select, where possible, one subject with five years or less of experience as a journeyman in the trade and one with more than five years of trade experience. It was thought that this procedure would produce a high proportion of returns, yield a greater variety of experience among respondents and avoid selection of marginal journeymen which might have occurred with the use of alternative selection procedures.

The "Instructor" category for each trade division sample was arrived at by simple random selection without replacement of five individuals from each of three lists of candidates compiled for the purpose. These three "Instructor" groups were then added to the appropriate "Supervisor" and "Journeyman" groups to complete the three samples. Thus the three samples, in their final form, each consisted of five "Supervisors", ten "Journeymen", and five "Instructors" giving a total of 60 subjects in all for the three samples.

The Research Instrument

The research instrument for the study was a questionnaire in the form of a mathematical checkoff list similar in structure to the one used by Laws in his 1966 study on the mathematical expectations of technicians (pp. 48 - 51). Respondents were asked to rate each of 45

mathematical knowledge and skill items on a three point Likert-type scale as either "Necessary" or "Desirable" or "Not Needed" for journeymen to possess in order that they may be able to practice their respective trades in a successful manner. Zeizel (1968) supported the use of checklists rather than numerical answers because the former reduced the number of "don't knows" (p. 48).

The mathematical competency items included in the questionnaire used for the study were derived from a number of sources including research reports, articles in learned journals, and from textbooks and other trade reference works.

Wilson (1952) reported the results of joint sessions of shop and mathematics teachers whose purpose was to carry out an analysis of the extent of use of applied mathematics in a number of representative skilled trades. A chart was compiled listing 16 mathematics topics and graphically illustrating whether or not they applied to each of the skilled trades (pp. 28 - 29).

A series of mathematical competencies whose application was thought to be fundamental to many skilled trades was presented by Carlton (1953). The author stressed the importance of a method of checking the accuracy of calculations in order to avoid costly mistakes in the shop (pp. 8 & 9).

Laws (1966) used a 104 item questionnaire for his study of mathematical expectations of technicians (pp. 48 - 51). Since mathematical skill items used by Laws were directed at technicians it was thought that they were too numerous and of too high an order of difficulty for the purposes of this study which was directed at journeymen. This conclusion was supported by a finding of the study by Laws that 47 out of

104 skills listed in the questionnaire were considered "not needed" by over 50 percent of the respondents and that only 23 out of the 104 skills listed in the questionnaire were considered "essential" by over 50 percent of the respondents (pp. 14 - 18).

Smith (1973) in a study which was conducted with workers and supervisors in a variety of geographical areas in the Province of Saskatchewan and whose purpose was to identify generic skill components of tasks and subtasks carried out in 27 different occupations used a questionnaire which included 70 mathematical skill items listed under 18 major mathematics topics (pp. 78 - 80).

Fitzgerald (1976) investigated the contents of mathematics programs provided by engineering companies for their beginning craft and technician apprentices and from the information obtained drew up a catalogue of mathematical items contained in these courses. These mathematical competencies were deemed necessary for beginning apprentices to possess because they would likely encounter problems which would require their application within the first few weeks of apprenticeship (pp. 43 & 44).

The list of 45 mathematical competencies included in the research instrument for this study was adapted from the above sources. In order to ensure that all the required mathematical competencies were included three textbooks or other trade reference works for each of the three selected trades were analyzed for mathematical content. It was found that all of the mathematical competencies encountered in these trade reference works had been included in the questionnaire and it was thought unlikely that further additions would be necessary.

The Likert-type scale with three response alternatives for each

questionnaire item which was used by Laws (1966) was adapted for use in this study (pp. 48 - 51).

The completed instrument was then submitted to a specialist in Mathematics Education from the Mathematics Department of The University of Alberta for review and criticism. This specialist recommended the inclusion in the questionnaire of a request directed to the respondent that he describe any mathematical shortcuts that might be used in the practice of his trade. The instrument was also reviewed by a specialist in instrument design form the Department of Educational Psychology of The University of Alberta. This specialist stated that the instrument appeared to be well designed and recommended that a pilot study be undertaken. A pilot study had been included in the original design of the study, so the only change required in the research instrument was the inclusion of a request of participants for mathematical shortcuts of their trade.

Pilot Study

A pilot study was carried out for the purpose of pointing up any possible errors or inadequacies which might have been present in the research instrument. The pilot study was conducted among a group of nine subjects selected on the basis of one representative for each stratum of each of the three populations included in the study. All but one of the pilot study participants remained as elements of the populations and were therefore eligible for selection as sample subjects for the main study. The lone exception was a welder who was not a population member by virtue of the fact that his place of business was located outside of the boundaries of the City of Edmonton.

Pilot study participants were contacted either by telephone or

in person, given a brief explanation of the purpose and method of the pilot study, and asked whether they would be willing to participate in the pilot study by completing a questionnaire. All individuals contacted agreed to participate in the pilot study. The Questionnaires were then posted or delivered to the participants along with a covering letter and a stamped self-addressed envelope.

The pilot study returns were examined by the researcher in order to identify inadequacies that might have been present in the research instrument. It was found that respondents had marked four of the mathematical knowledge and skill items with either an asterisk or a question mark. It appeared that these respondents may have experienced difficulty in understanding the meaning of these items thereby eliciting responses which might be considered invalid. It was therefore decided to attempt to clarify the meaning of three of the mathematical knowledge and skill items by changing the wording in such a manner as to include one or more examples.

The pilot study returns were examined by a staff member of the Department of Industrial and Vocational Education at The University of Alberta and were found to have an acceptable distribution of responses among the three scale alternatives in the questionnaire.

The modified and corrected instrument was printed and readied for distribution along with a stamped self-addressed envelope and a covering letter outlining the purpose and briefly explaining the methodology of the study.

Distribution of Research Instruments

For the "Supervisors" and "Journeymen" groups, arrangements were made by the researcher to visit the supervisors of each of the fifteen

selected employing agencies for the purpose of delivering the research instruments and obtaining the names of the subjects selected to complete the instruments. The supervisors were asked for their cooperation in expediting the completion and return of the questionnaires. Follow-up calls were made with the result that completed questionnaires were received within a short time after the calls were placed. One exception was the case of a heavy duty repair shop whose foreman informed the researcher that he and his men were working long hours and did not have time to fill out their questionnaires.

For the "Instructor" category, the subjects were contacted by telephone and given a brief outline of the purpose and methodology of the study. These subjects were then asked to complete and return the questionnaire which would be forwarded to them along with a covering letter and a stamped self-addressed envelope.

For tabulation purposes, practicing certificated journeymen with 5 years or less of experience in their respective trades were placed in "Group A" and journeymen with over 5 years of such experience were assigned to "Group B".

Returns were received from a total of 50 respondents which is equivalent to 83.3 percent of the number of questionnaires which were distributed. Numbers and percent proportions of returns by sample subgroup are shown in Table 1.

TABLE I

RETURNS BY SAMPLE SUBGROUP

	Motor Mechanics	Heavy Duty Mechanics	Welders	Totals
Supervisors				
Posted	5	5	5	15
Returned	5	3	4	12
Percent	100	60	80	80
Journeymen				
Group A				
Posted	5	5	5	15
Returned	5	3	4	12
Percent	100	60	80	80
Group B				
Posted	5	5	5	15
Returned	4	5	3	12
Percent	80	100	60	80
Instructors				
Posted	5	5	5	15
Returned	5	4	5	14
Percent	100	80	100	93.3

These data show that the Instructor group had the highest proportion of returns with 93.3 percent of the research instruments having been completed and returned to the researcher.

Data Tabulation for the Motor Mechanics Sample

Table II shows mathematical knowledges and skills frequencies obtained from five completed research instruments returned by supervisors from the Motor Mechanics sample.

Table III shows mathematical skills frequencies obtained from five completed research instruments returned by group A[1] journeymen from the Motor Mechanics sample.

Table IV shows mathematical skills and frequencies obtained from four completed research instruments returned by group B[2] journeymen from the Motor Mechanics sample.

Table V shows mathematical knowledges and skills frequencies obtained from five completed research instruments returned by instructors from the Motor Mechanics sample.

Table VI shows mathematical knowledges and skills frequencies and percentages combined for the 19 respondents from the Motor Mechanics sample.

---

[1] Group A = journeymen having 5 years or less of experience in their trade.

[2] Group B = journeymen having more than 5 years of experience in their trade.

TABLE II

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR SUPERVISOR GROUP - MOTOR MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, −, x, ÷) with whole numbers.	5	0	0
Basic operations with common fractions.	5	0	0
Basic operations with decimals and percent.	4	1	0
Conversion of common fractions to decimals or percent and vice versa.	4	0	1
Using percent to calculate interest, mark-up and/or discount.	2	1	2
Knowing common metric weights and measures.	5	0	0
Knowing common English weights and measures.	3	1	1
Converting English to metric weights and measures.	4	1	0
Measuring with rule or tape.	5	0	0
Measuring with micrometer.	5	0	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	2	2	1
Reading gauges and meters.	5	0	0
Calculating ratio and/or proportion.	4	1	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	1	2	2
Finding Powers of numbers.	0	1	4
Using mathematical tables.	1	3	1
Calculating square root.	1	1	3
Using scientific notation (powers of 10).	0	2	3
Using common logarithms to solve mathematical problems.	1	0	4
Basic operations with positive and negative numbers.	1	0	4
Basic operations with literal expressions (algebra).	1	2	2
Interpreting line and/or bar graphs.	0	3	2

TABLE II (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	2	3
Applying formulas (by substitution of numerical values).	1	2	2
Solving linear equations.	1	0	4
Transposing, factoring and cancellation.	1	0	4
Solving simultaneous equations.	1	0	4
Solving quadratic equations.	0	1	4
Knowing meaning of parallelism between lines and/or planes.	1	3	1
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	1	3	1
Measuring angles.	4	1	0
Laying out or adjusting angles to given number of degrees.	3	2	0
Calculating area of square or rectangle.	1	3	1
Calculating circumference and/or area of circle.	1	3	1
Finding unknown side of right triangle (Pythagorean theorem).	1	1	3
Finding area and/or volume of rectangular solids, (e.g. tanks).	1	2	2
Finding area and/or volume of cylinders.	2	2	1
Interpreting "pie" or circle graphs.	1	1	3
Constructing "pie" or circle graphs.	1	1	3
Using slide rule to solve mathematical problems.	0	4	1
Using calculator for basic operations.	0	3	2
Knowledge of set theory.	1	3	1
Completing business forms, (e.g. invoices, work orders, bills of sale).	2	2	1
Record keeping.	2	2	1
Solving vector analysis problems.	1	1	3

TABLE III

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR GROUP A[1] JOURNEYMEN - MOTOR MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, −, ×, ÷) with whole numbers.	4	0	1
Basic operations with common fractions.	5	0	0
Basic operations with decimals and percent.	5	0	0
Conversion of common fractions to decimals or percent and vice versa.	4	1	0
Using percent to calculate interest, mark-up and/or discount.	2	2	1
Knowing common metric weights and measures.	3	2	0
Knowing common English weights and measures.	3	1	1
Converting English to metric weights and measures.	3	2	0
Measuring with rule or tape.	5	0	0
Measuring with micrometer.	5	0	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	5	0	0
Reading gauges and meters.	5	0	0
Calculating ratio and/or proportion.	4	1	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	3	2	0
Finding Powers of numbers.	0	1	4
Using mathematical tables.	1	2	2
Calculating square root.	0	0	5
Using scientific notation (powers of 10).	0	0	5
Using common logarithms to solve mathematical problems.	1	1	3
Basic operations with positive and negative numbers.	1	2	2
Basic operations with literal expressions (algebra).	1	3	1
Interpreting line and/or bar graphs.	1	3	1

---

[1] Group A = Journeymen having 5 years or less of experience in their trade.

TABLE III (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	1	3	1
Applying formulas (by substitution of numerical values).	1	2	2
Solving linear equations.	0	2	3
Transposing, factoring and cancellation.	0	2	3
Solving simultaneous equations.	0	0	5
Solving quadratic equations.	0	1	4
Knowing meaning of parallelism between lines and/or planes.	1	1	3
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	3	0	1
Measuring angles.	3	2	0
Laying out or adjusting angles to given number of degrees.	4	0	1
Calculating area of square or rectangle.	2	1	2
Calculating circumference and/or area of circle.	3	1	1
Finding unknown side of right triangle (Pythagorean theorem).	0	2	3
Finding area and/or volume of rectangular solids, (e.g. tanks).	1	3	1
Finding area and/or volume of cylinders.	2	2	1
Interpreting "pie" or circle graphs.	1	2	2
Constructing "pie" or circle graphs.	1	1	3
Using slide rule to solve mathematical problems.	0	2	3
Using calculator for basic operations.	0	4	1
Knowledge of set theory.	2	1	2
Completing business forms, (e.g. invoices, work orders, bills of sale).	3	2	0
Record keeping.	2	3	0
Solving vector analysis problems.	0	2	3

TABLE IV

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR GROUP B[2] JOURNEYMEN - MOTOR MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, −, ×, ÷) with whole numbers.	4	0	0
Basic operations with common fractions.	4	0	0
Basic operations with decimals and percent.	4	0	0
Conversion of common fractions to decimals or percent and vice versa.	4	0	0
Using percent to calculate interest, mark-up and/or discount.	1	2	1
Knowing common metric weights and measures.	3	1	0
Knowing common English weights and measures.	3	0	1
Converting English to metric weights and measures.	3	1	0
Measuring with rule or tape.	4	0	0
Measuring with micrometer.	4	0	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	4	0	0
Reading gauges and meters.	4	0	0
Calculating ratio and/or proportion.	3	1	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	2	1	1
Finding Powers of numbers.	0	1	3
Using mathematical tables.	3	1	0
Calculating square root.	1	0	3
Using scientific notation (powers of 10).	0	1	3
Using common logarithms to solve mathematical problems.	1	0	3
Basic operations with positive and negative numbers.	1	2	1
Basic operations with literal expressions (algebra).	0	1	3
Interpreting line and/or bar graphs.	1	1	2

---

[2] Group B = Journeymen having more than 5 years of experience in their trade.

TABLE IV (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	0	4
Applying formulas (by substitution of numerical values).	0	0	4
Solving linear equations.	0	0	4
Transposing, factoring and cancellation.	0	0	4
Solving simultaneous equations.	0	0	4
Solving quadratic equations.	0	0	4
Knowing meaning of parallelism between lines and/or planes.	1	1	2
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	3	1	0
Measuring angles.	3	1	0
Laying out or adjusting angles to given number of degrees.	3	1	0
Calculating area of square or rectangle.	2	2	0
Calculating circumference and/or area of circle.	3	1	0
Finding unknown side of right triangle (Pythagorean theorem).	0	1	3
Finding area and/or volume of rectangular solids, (e.g. tanks).	2	2	0
Finding area and/or volume of cylinders.	2	2	0
Interpreting "pie" or circle graphs.	2	1	1
Constructing "pie" or circle graphs.	1	1	2
Using slide rule to solve mathematical problems.	1	2	1
Using calculator for basic operations.	0	2	2
Knowledge of set theory.	2	0	2
Completing business forms, (e.g. invoices, work orders, bills of sale).	1	3	0
Record keeping.	1	3	0
Solving vector analysis problems.	0	0	4

TABLE V

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR INSTRUCTOR GROUP - MOTOR MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, −, x, ÷) with whole numbers.	5	0	0
Basic operations with common fractions.	4	1	0
Basic operations with decimals and percent.	4	1	0
Conversion of common fractions to decimals or percent and vice versa.	4	1	0
Using percent to calculate interest, mark-up and/or discount.	4	1	0
Knowing common metric weights and measures.	2	2	1
Knowing common English weights and measures.	5	0	0
Converting English to metric weights and measures.	1	3	1
Measuring with rule or tape.	4	1	0
Measuring with micrometer.	3	2	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	2	3	0
Reading gauges and meters.	4	1	0
Calculating ratio and/or proportion.	4	1	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	2	3	0
Finding Powers of numbers.	0	1	4
Using mathematical tables.	0	5	0
Calculating square root.	0	1	4
Using scientific notation (powers of 10).	0	2	3
Using common logarithms to solve mathematical problems.	0	1	4
Basic operations with positive and negative numbers.	1	3	1
Basic operations with literal expressions (algebra).	1	1	3
Interpreting line and/or bar graphs.	2	3	1

TABLE V (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	2	2	1
Applying formulas (by substitution of numerical values).	1	4	0
Solving linear equations.	1	2	2
Transposing, factoring and cancellation.	2	1	2
Solving simultaneous equations.	1	0	4
Solving quadratic equations.	1	0	4
Knowing meaning of parallelism between lines and/or planes.	2	2	1
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	5	0	0
Measuring angles.	4	1	0
Laying out or adjusting angles to given number of degrees.	4	1	0
Calculating area of square or rectangle.	4	1	0
Calculating circumference and/or area of circle.	4	1	0
Finding unknown side of right triangle (Pythagorean theorem).	1	2	2
Finding area and/or volume of rectangular solids, (e.g. tanks).	3	2	0
Finding area and/or volume of cylinders.	4	1	0
Interpreting "pie" or circle graphs.	3	0	2
Constructing "pie" or circle graphs.	1	2	2
Using slide rule to solve mathematical problems.	0	4	1
Using calculator for basic operations.	0	3	2
Knowledge of set theory.	0	0	5
Completing business forms, (e.g. invoices, work orders, bills of sale).	4	1	0
Record keeping.	4	1	0
Solving vector analysis problems.	0	1	4

TABLE VI

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES AND PERCENTAGES FOR MOTOR MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY		DESIRABLE		NOT NEEDED	
	NO.	%	NO.	%	NO.	%
Basic operations (+, -, x, ÷) with whole numbers.	18	94.7	0	0.0	1	5.3
Basic operation with common fractions.	18	94.7	1	5.3	0	0.0
Basic operations with decimals and percent.	17	89.5	2	10.5	0	0.0
Conversion of common fractions to decimals or percent and vice versa.	16	84.2	2	10.5	1	5.3
Using percent to calculate interest, mark-up and/or discount.	9	47.4	6	31.6	4	21.1
Knowing common metric weights and measures.	13	68.4	5	26.3	1	5.3
Knowing common English weights and measures.	14	73.7	2	10.5	3	15.8
Converting English to metric weights and measures.	11	57.9	7	36.8	1	5.3
Measuring with rule or tape.	18	94.7	1	5.3	0	0.0
Measuring with micrometer.	17	89.5	2	10.5	0	0.0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	13	68.4	5	26.3	1	5.3
Reading gauges and meters.	18	94.7	1	5.3	0	0.0
Calculating ratio and/or proportion.	15	78.9	4	21.1	0	0.0
Solving ratio and proportion problems (e.g. interpreting scale drawings).	8	42.1	8	42.1	3	15.8
Finding Powers of numbers.	0	0.0	4	21.1	15	78.9
Using mathematical tables.	5	26.3	11	57.9	3	15.8
Calculating square root.	2	10.5	2	10.5	15	78.9
Using scientific notation (powers of 10).	0	0.0	5	26.3	14	73.7
Using common logarithms to solve mathematical problems.	3	15.8	2	10.5	14	73.7
Basic operations with positive and negative numbers.	4	21.1	7	36.8	8	42.1
Basic operations with literal expressions (algebra).	3	15.8	7	36.8	9	47.4
Interpreting line and/or bar graphs.	4	21.1	10	52.6	5	26.3

TABLE VI (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY NO.	NECESSARY %	DESIRABLE NO.	DESIRABLE %	NOT NEEDED NO.	NOT NEEDED %
Constructing line and/or bar graphs.	3	15.8	7	36.8	9	47.4
Applying formulas (by substitution of numerical values).	3	15.8	8	42.1	8	42.1
Solving linear equations.	2	10.5	4	21.1	13	68.4
Transposing, factoring and cancellation.	3	15.8	3	15.8	13	68.4
Solving simultaneous equations.	2	10.5	0	0.0	17	89.5
Solving quadratic equations.	1	5.3	2	10.5	16	84.2
Knowing meaning of parallelism between lines and/or planes.	5	26.3	7	36.8	7	36.8
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	12	63.2	5	26.3	2	10.5
Measuring angles.	14	73.7	5	26.3	0	0.0
Laying out or adjusting angles to given number of degrees.	14	73.7	4	21.1	1	5.3
Calculating area of square or rectangle.	9	47.4	7	36.8	3	15.8
Calculating circumference and/or area of circle.	11	57.9	6	31.6	2	10.5
Finding unknown side of right triangle (Pythagorean theorem).	2	10.5	6	31.6	11	57.9
Find area and/or volume of rectangular solids, (e.g. tanks).	7	36.8	9	47.4	3	15.8
Finding area and/or volume of cylinders.	10	52.6	7	36.8	2	10.5
Interpreting "pie" or circle graphs.	7	36.8	4	21.1	8	42.1
Constructing "pie" or circle graphs.	4	21.1	5	26.3	10	52.6
Using slide rule to solve mathematical problems.	1	5.3	12	63.2	6	31.6
Using calculator for basic operations.	0	0.0	12	63.2	7	36.8
Knowledge of set theory.	5	26.3	4	21.1	10	52.6
Completing business forms, (e.g. invoices, work orders, bills of sale).	10	52.6	8	42.1	1	5.3
Record keeping.	9	47.4	9	47.4	1	5.3
Solving vector analysis problems.	1	5.3	4	21.1	14	73.7

Data Tabulation for the Heavy Duty Mechanics Sample

Table VII shows mathematical knowledges and skills frequencies obtained from three completed research instruments returned by supervisors from the Heavy Duty Mechanics sample.

Table VIII shows mathematical knowledges and skills frequencies obtained from three completed research instruments returned by group A[1] journeymen from the Heavy Duty Mechanics sample.

Table IX shows mathematical knowledges and skills frequencies obtained from five completed research instruments returned by group B[2] journeymen from the Heavy Duty Mechanics sample.

Table X shows mathematical knowledges and skills frequencies obtained from four completed research instruments returned by instructors from the Heavy Duty Mechanics sample.

Table XI shows mathematical knowledges and skills frequencies and percentages combined for the 15 respondents from the Heavy Duty Mechanics sample.

---

[1] Group A = journeymen having 5 years or less of experience in their trade.

[2] Group B = journeymen having more than 5 years of experience in their trade.

TABLE VII

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR SUPERVISOR GROUP - HEAVY DUTY MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, −, x, ÷) with whole numbers.	2	1	0
Basic operations with common fractions.	2	1	0
Basic operations with decimals and percent.	2	0	1
Conversion of common fractions to decimals or percent and vice versa.	0	2	1
Using percent to calculate interest, mark-up and/or discount.	0	2	1
Knowing common metric weights and measures.	1	2	0
Knowing common English weights and measures.	3	0	0
Converting English to metric weights and measures.	1	2	0
Measuring with rule or tape.	3	0	0
Measuring with micrometer.	3	0	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	2	0	1
Reading gauges and meters.	3	0	0
Calculating ratio and/or proportion.	1	2	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	0	2	1
Finding Powers of numbers.	0	2	1
Using mathematical tables.	0	2	1
Calculating square root.	0	1	2
Using scientific notation (powers of 10).	1	0	2
Using common logarithms to solve mathematical problems.	0	1	2
Basic operations with positive and negative numbers.	1	1	1
Basic operations with literal expressions (algebra).	0	1	2
Interpreting line and/or bar graphs.	0	1	2

TABLE VII (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	1	2
Applying formulas (by substitution of numerical values).	0	1	2
Solving linear equations.	0	1	2
Transposing, factoring and cancellation.	0	1	2
Solving simultaneous equations.	0	1	2
Solving quadratic equations.	0	1	2
Knowing meaning of parallelism between lines and/or planes.	0	1	2
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	1	1	1
Measuring angles.	1	2	0
Laying out or adjusting angles to given number of degrees.	1	1	1
Calculating area of square or rectangle.	1	1	1
Calculating circumference and/or area of circle.	1	1	1
Finding unknown side of right triangle (Pythagorean theorem).	0	2	1
Finding area and/or volume of rectangular solids, (e.g. tanks).	1	2	0
Finding area and/or volume of cylinders.	2	1	0
Interpreting "pie" or circle graphs.	0	2	1
Constructing "pie" or circle graphs.	0	2	1
Using slide rule to solve mathematical problems.	0	2	1
Using calculator for basic operations.	0	3	0
Knowledge of set theory.	1	1	1
Completing business forms, (e.g. invoices, work orders, bills of sale).	2	1	0
Record keeping.	2	1	0
Solving vector analysis problems.	1	2	0

TABLE VIII

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR GROUP A[1] JOURNEYMEN - HEAVY DUTY MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, -, x, ÷) with whole numbers.	3	0	0
Basic operations with common fractions.	3	0	0
Basic operations with decimals and percent.	3	0	0
Conversion of common fractions to decimals or percent and vice versa.	1	2	0
Using percent to calculate interest, mark-up and/or discount.	0	2	1
Knowing common metric weights and measures.	2	1	0
Knowing common English weights and measures.	3	0	0
Converting English to metric weights and measures.	2	1	1
Measuring with rule or tape.	3	0	0
Measuring with micrometer.	3	0	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	2	1	0
Reading gauges and meters.	3	0	0
Calculating ratio and/or proportion.	1	2	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	1	1	1
Finding Powers of numbers.	0	1	2
Using mathematical tables.	0	2	1
Calculating square root.	0	1	2
Using scientific notation (powers of 10).	0	1	2
Using common logarithms to solve mathematical problems.	0	0	3
Basic operations with positive and negative numbers.	1	1	1
Basic operations with literal expressions (algebra).	1	1	1
Interpreting line and/or bar graphs.	2	1	0

---

[1] Group A = Journeymen having 5 years or less of experience in their trade.

TABLE VIII (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	2	1
Applying formulas (by substitution of numerical values).	1	1	1
Solving linear equations.	0	1	2
Transposing, factoring and cancellation.	0	1	2
Solving simultaneous equations.	0	1	2
Solving quadratic equations.	0	0	3
Knowing meaning of parallelism between lines and/or planes.	1	1	1
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	2	0	1
Measuring angles.	2	1	0
Laying out or adjusting angles to given number of degrees.	2	0	1
Calculating area of square or rectangle.	2	0	1
Calculating circumference and/or area of circle.	2	0	1
Finding unknown side of right triangle (Pythagorean theorem).	0	1	2
Finding area and/or volume of rectangular solids, (e.g. tanks).	2	0	1
Finding area and/or volume of cylinders.	2	0	1
Interpreting "pie" or circle graphs.	2	0	1
Constructing "pie" or circle graphs.	1	1	1
Using slide rule to solve mathematical problems.	0	1	2
Using calculator for basic operations.	0	1	2
Knowledge of set theory.	0	1	2
Completing business forms, (e.g. invoices, work orders, bills of sale).	2	1	0
Record keeping.	1	2	0
Solving vector analysis problems.	0	0	2

TABLE IX

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR GROUP B[2] JOURNEYMEN - HEAVY DUTY MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, -, x, ÷) with whole numbers.	5	0	0
Basic operations with common fractions.	4	1	0
Basic operations with decimals and percent.	4	1	0
Conversion of common fractions to decimals or percent and vice versa.	3	2	0
Using percent to calculate interest, mark-up and/or discount.	3	2	0
Knowing common metric weights and measures.	2	3	0
Knowing common English weights and measures.	5	0	0
Converting English to metric weights and measures.	1	3	1
Measuring with rule or tape.	4	1	0
Measuring with micrometer.	5	0	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	4	1	0
Reading gauges and meters.	5	0	0
Calculating ratio and/or proportion.	5	0	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	4	1	0
Finding Powers of numbers.	1	3	1
Using mathematical tables.	3	2	0
Calculating square root.	1	1	3
Using scientific notation (powers of 10).	1	1	3
Using common logarithms to solve mathematical problems.	2	1	2
Basic operations with positive and negative numbers.	1	1	3
Basic operations with literal expressions (algebra).	1	1	3
Interpreting line and/or bar graphs.	2	3	0

---

[2] Group B = Journeymen having more than 5 years of experience in their trade.

TABLE IX (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	4	1
Applying formulas (by substitution of numerical values).	1	1	3
Solving linear equations.	1	2	2
Transposing, factoring and cancellation.	1	2	2
Solving simultaneous equations.	1	2	2
Solving quadratic equations.	0	2	3
Knowing meaning of parallelism between lines and/or planes.	2	2	1
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	2	3	0
Measuring angles.	2	3	0
Laying out or adjusting angles to given number of degrees.	2	2	1
Calculating area of square or rectangle.	0	4	0
Calculating circumference and/or area of circle.	2	3	0
Finding unknown side of right triangle (Pythagorean theorem).	0	3	2
Finding area and/or volume of rectangular solids, (e.g. tanks).	0	5	0
Finding area and/or volume of cylinders.	3	2	0
Interpreting "pie" or circle graphs.	0	3	2
Constructing "pie" or circle graphs.	0	3	2
Using slide rule to solve mathematical problems.	0	3	2
Using calculator for basic operations.	1	3	1
Knowledge of set theory.	2	1	1
Completing business forms, (e.g. invoices, work orders, bills of sale).	3	2	0
Record keeping.	3	2	0
Solving vector analysis problems.	1	2	2

TABLE X

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR INSTRUCTOR GROUP - HEAVY DUTY MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, -, x, ÷) with whole numbers.	4	0	0
Basic operations with common fractions.	4	0	0
Basic operations with decimals and percent.	4	0	0
Conversion of common fractions to decimals or percent and vice versa.	4	0	0
Using percent to calculate interest, mark-up and/or discount.	0	3	1
Knowing common metric weights and measures.	3	1	0
Knowing common English weights and measures.	4	0	0
Converting English to metric weights and measures.	4	0	0
Measuring with rule or tape.	4	0	0
Measuring with micrometer.	4	0	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	4	0	0
Reading gauges and meters.	4	0	0
Calculating ratio and/or proportion.	2	2	1
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	3	0	1
Finding Powers of numbers.	0	0	3
Using mathematical tables.	0	2	2
Calculating square root.	0	1	3
Using scientific notation (powers of 10).	0	0	4
Using common logarithms to solve mathematical problems.	0	0	4
Basic operations with positive and negative numbers.	2	1	1
Basic operations with literal expressions (algebra).	1	3	0
Interpreting line and/or bar graphs.	1	3	0

TABLE X (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	2	2
Applying formulas (by substitution of numerical values).	1	2	1
Solving linear equations.	1	1	2
Transposing, factoring and cancellation.	1	0	3
Solving simultaneous equations.	0	0	4
Solving quadratic equations.	0	0	4
Knowing meaning of parallelism between lines and/or planes.	1	1	2
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	4	0	0
Measuring angles.	4	0	0
Laying out or adjusting angles to given number of degrees.	3	1	0
Calculating area of square or rectangle.	3	1	0
Calculating circumference and/or area of circle.	3	1	0
Finding unknown side of right triangle (Pythagorean theorem).	0	4	0
Finding area and/or volume of rectangular solids, (e.g. tanks).	4	0	0
Finding area and/or volume of cylinders.	4	0	0
Interpreting "pie" or circle graphs.	1	1	2
Constructing "pie" or circle graphs.	0	1	2
Using slide rule to solve mathematical problems.	1	2	2
Using calculator for basic operations.	0	4	0
Knowledge of set theory.	1	0	3
Completing business forms, (e.g. invoices, work orders, bills of sale).	2	1	1
Record keeping.	2	1	1
Solving vector analysis problems.	0	0	3

TABLE XI

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR PERCENTAGES FOR HEAVY DUTY MECHANICS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY		DESIRABLE		NOT NEEDED	
	NO.	%	NO.	%	NO.	%
Basic operations (+, −, x, ÷) with whole numbers.	14	93.3	1	6.7	0	0.0
Basic operation with common fractions.	13	86.7	2	13.3	0	0.0
Basic operations with decimals and percent.	13	86.7	1	6.7	1	6.7
Conversion of common fractions to decimals or percent and vice versa.	8	53.5	6	40.0	1	6.7
Using percent to calculate interest, mark-up and/or discount.	3	20.0	9	60.0	3	20.0
Knowing common metric weights and measures.	8	53.3	7	46.7	0	0.0
Knowing common English weights and measures.	15	100.0	0	0.0	0	0.0
Converting English to metric weights and measures.	8	53.3	6	40.4	1	6.7
Measuring with rule or tape.	14	93.3	1	6.7	0	0.0
Measuring with micrometer.	15	100.0	0	0.0	0	0.0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	12	80.0	2	13.3	1	6.7
Reading gauges and meters.	15	100.0	0	0.0	0	0.0
Calculating ratio and/or proportion.	9	60.0	6	40.0	0	0.0
Solving ratio and proportion problems (e.g. interpreting scale drawings).	8	53.3	4	26.7	3	20.0
Finding Powers of numbers.	1	7.1	6	42.9	7	50.0
Using mathematical tables.	3	20.0	8	53.3	4	26.7
Calculating square root.	1	6.7	4	26.7	10	66.7
Using scientific notation (powers of 10).	2	13.3	2	13.3	11	73.3
Using common logarithms to solve mathematical problems.	2	13.3	2	13.3	11	73.3
Basic operations with positive and negative numbers.	5	33.3	4	26.7	6	40.0
Basic operations with literal expressions (algebra).	3	20.0	6	40.0	6	40.0
Interpreting line and/or bar graphs.	5	33.3	8	53.3	2	13.3

TABLE XI (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY NO.	NECESSARY %	DESIRABLE NO.	DESIRABLE %	NOT NEEDED NO.	NOT NEEDED %
Constructing line and/or bar graphs.	0	0.0	9	60.0	6	40.0
Applying formulas (by substitution of numerical values).	3	20.0	5	33.3	7	46.7
Solving linear equations.	2	13.3	5	33.3	8	53.3
Transposing, factoring and cancellation.	2	13.3	4	26.7	9	60.0
Solving simultaneous equations.	1	6.7	4	26.7	10	66.7
Solving quadratic equations.	0	0.0	3	20.0	12	80.0
Knowing meaning of parallelism between lines and/or planes.	4	26.7	5	33.3	6	40.0
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	9	60.0	4	26.7	2	13.3
Measuring angles.	9	60.0	6	40.0	0	0.0
Laying out or adjusting angles to given number of degrees.	8	53.3	4	26.7	3	20.0
Calculating area of square or rectangle.	6	42.9	6	42.9	2	14.3
Calculating circumference and/or area of circle.	8	53.3	5	33.3	2	13.3
Finding unknown side of right triangle (Pythagorean theorem).	0	0.0	10	66.7	5	33.3
Find area and/or volume of rectangular solids, (e.g. tanks).	7	46.7	7	46.7	1	6.7
Finding area and/or volume of cylinders.	11	73.3	3	20.0	1	6.7
Interpreting "pie" or circle graphs.	3	20.0	6	40.0	6	40.0
Constructing "pie" or circle graphs.	1	7.1	7	50.0	6	42.9
Using slide rule to solve mathematical problems.	0	0.0	8	53.3	7	46.7
Using calculator for basic operations.	1	6.7	11	73.3	3	20.0
Knowledge of set theory.	4	26.7	3	21.4	7	50.0
Completing business forms, (e.g. invoices, work orders, bills of sale).	9	60.0	5	33.3	1	6.7
Record keeping.	8	53.3	6	40.0	1	6.7
Solving vector analysis problems.	2	15.4	4	30.8	11	53.8

Data Tabulation for the Welders Sample

Table XII shows mathematical knowledges and skills frequencies obtained from four completed research instruments returned by supervisors from the Welders sample.

Table XIII shows mathematical knowledges and skills frequencies obtained from four completed research instruments returned by group A[1] journeymen from the Welders sample.

Table XIV shows mathematical knowledges and skills frequencies obtained from three completed research instruments returned by group B[2] journeymen from the Welders sample.

Table XV shows mathematical knowledges and skills frequencies obtained from five completed research instruments returned by instructors from the Welders sample.

Table XVI shows mathematical knowledges and skills frequencies and percentages combined for the 16 respondents from the Welders sample.

---

[1] Group A = journeymen having 5 years or less of experience in their trade.

[2] Group B = journeymen having more than 5 years of experience in their trade.

TABLE XII

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR SUPERVISOR - WELDERS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, −, x, ÷) with whole numbers.	4	0	0
Basic operations with common fractions.	4	0	0
Basic operations with decimals and percent.	4	0	0
Conversion of common fractions to decimals or percent and vice versa.	4	0	0
Using percent to calculate interest, mark-up and/or discount.	2	2	0
Knowing common metric weights and measures.	2	0	2
Knowing common English weights and measures.	4	0	0
Converting English to metric weights and measures.	1	2	1
Measuring with rule or tape.	4	0	0
Measuring with micrometer.	2	1	0
Estimation of measurements, (e.g. hold electrode 1/8" from work).	4	0	0
Reading gauges and meters.	4	0	0
Calculating ratio and/or proportion.	2	2	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	3	1	0
Finding Powers of numbers.	1	2	1
Using mathematical tables.	3	1	0
Calculating square root.	2	1	1
Using scientific notation (powers of 10).	0	2	2
Using common logarithms to solve mathematical problems.	1	3	0
Basic operations with positive and negative numbers.	2	2	0
Basic operations with literal expressions (algebra).	1	3	0
Interpreting line and/or bar graphs.	2	2	0

TABLE XII (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	1	3	0
Applying formulas (by substitution of numerical values).	3	1	0
Solving linear equations.	2	2	0
Transposing, factoring and cancellation.	1	3	0
Solving simultaneous equations.	0	3	1
Solving quadratic equations.	0	2	2
Knowing meaning of parallelism between lines and/or planes.	3	1	0
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	4	0	0
Measuring angles.	4	0	0
Laying out or adjusting angles to given number of degrees.	4	0	0
Calculating area of square or rectangle.	4	0	0
Calculating circumference and/or area of circle.	4	0	0
Finding unknown side of right triangle (Pythagorean theorem).	1	3	0
Finding area and/or volume of rectangular solids, (e.g. tanks).	4	0	0
Finding area and/or volume of cylinders.	4	0	0
Interpreting "pie" or circle graphs.	2	2	0
Constructing "pie" or circle graphs.	2	2	0
Using slide rule to solve mathematical problems.	1	3	0
Using calculator for basic operations.	2	2	0
Knowledge of set theory.	2	1	1
Completing business forms, (e.g. invoices, work orders, bills of sale).	2	1	1
Record keeping.	3	0	1
Solving vector analysis problems.	1	1	2

TABLE XIII

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR GROUP A[1] JOURNEYMEN - WELDERS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, -, x, ÷) with whole numbers.	4	0	0
Basic operations with common fractions.	4	0	0
Basic operations with decimals and percent.	2	2	0
Conversion of common fractions to decimals or percent and vice versa.	2	2	0
Using percent to calculate interest, mark-up and/or discount.	2	1	1
Knowing common metric weights and measures.	0	3	1
Knowing common English weights and measures.	4	0	0
Converting English to metric weights and measures.	0	3	1
Measuring with rule or tape.	4	0	0
Measuring with micrometer.	0	3	1
Estimation of measurements, (e.g. hold electrode 1/8" from work).	4	0	0
Reading gauges and meters.	2	2	0
Calculating ratio and/or proportion.	2	2	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	2	2	0
Finding Powers of numbers.	2	0	2
Using mathematical tables.	2	2	0
Calculating square root.	3	1	0
Using scientific notation (powers of 10).	0	2	2
Using common logarithms to solve mathematical problems.	0	2	2
Basic operations with positive and negative numbers.	1	1	2
Basic operations with literal expressions (algebra).	0	2	2
Interpreting line and/or bar graphs.	0	2	2

---

[1] Group A = Journeymen having 5 years or less of experience in their trade.

TABLE XIII (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	2	2
Applying formulas (by substitution of numerical values).	1	2	1
Solving linear equations.	1	3	0
Transposing, factoring and cancellation.	2	0	2
Solving simultaneous equations.	0	2	2
Solving quadratic equations.	0	2	2
Knowing meaning of parallelism between lines and/or planes.	3	1	0
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	4	0	0
Measuring angles.	4	0	0
Laying out or adjusting angles to given number of degrees.	3	1	0
Calculating area of square or rectangle.	4	0	0
Calculating circumference and/or area of circle.	4	0	0
Finding unknown side of right triangle (Pythagorean theorem).	3	0	1
Finding area and/or volume of rectangular solids, (e.g. tanks).	4	0	0
Finding area and/or volume of cylinders.	4	0	0
Interpreting "pie" or circle graphs.	3	0	1
Constructing "pie" or circle graphs.	3	0	1
Using slide rule to solve mathematical problems.	1	2	1
Using calculator for basic operations.	3	1	0
Knowledge of set theory.	3	0	1
Completing business forms, (e.g. invoices, work orders, bills of sale).	2	2	0
Record keeping.	2	2	0
Solving vector analysis problems.	0	2	2

TABLE XIV

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR GROUP B[2] JOURNEYMEN - WELDERS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, −, x, ÷) with whole numbers.	3	0	0
Basic operations with common fractions.	3	0	0
Basic operations with decimals and percent.	1	1	1
Conversion of common fractions to decimals or percent and vice versa.	1	1	1
Using percent to calculate interest, mark-up and/or discount.	0	2	1
Knowing common metric weights and measures.	0	3	0
Knowing common English weights and measures.	3	0	0
Converting English to metric weights and measures.	0	2	1
Measuring with rule or tape.	3	0	0
Measuring with micrometer.	1	1	1
Estimation of measurements, (e.g. hold electrode 1/8" from work).	3	0	0
Reading gauges and meters.	3	0	0
Calculating ratio and/or proportion.	1	2	0
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	2	1	0
Finding Powers of numbers.	0	2	1
Using mathematical tables.	2	1	0
Calculating square root.	0	3	0
Using scientific notation (powers of 10).	1	2	0
Using common logarithms to solve mathematical problems.	1	0	2
Basic operations with positive and negative numbers.	2	0	1
Basic operations with literal expressions (algebra).	0	2	1
Interpreting line and/or bar graphs.	1	1	1

---

[2] Group B = Journeymen having more than 5 years of experience in their trade.

TABLE XIV (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	1	1	1
Applying formulas (by substitution of numerical values).	1	1	1
Solving linear equations.	1	0	2
Transposing, factoring and cancellation.	0	1	2
Solving simultaneous equations.	0	1	2
Solving quadratic equations.	0	1	2
Knowing meaning of parallelism between lines and/or planes.	2	1	0
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	3	0	0
Measuring angles.	3	0	0
Laying out or adjusting angles to given number of degrees.	3	0	0
Calculating area of square or rectangle.	2	1	0
Calculating circumference and/or area of circle.	3	0	0
Finding unknown side of right triangle (Pythagorean theorem).	1	2	0
Finding area and/or volume of rectangular solids, (e.g. tanks).	1	2	0
Finding area and/or volume of cylinders.	1	2	0
Interpreting "pie" or circle graphs.	2	1	0
Constructing "pie" or circle graphs.	2	1	0
Using slide rule to solve mathematical problems.	0	3	0
Using calculator for basic operations.	0	2	0
Knowledge of set theory.	0	2	0
Completing business forms, (e.g. invoices, work orders, bills of sale).	0	1	2
Record keeping.	0	2	1
Solving vector analysis problems.	0	1	2

TABLE XV

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR INSTRUCTOR GROUP - WELDERS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Basic operations (+, -, x, ÷) with whole numbers.	5	0	0
Basic operations with common fractions.	5	0	0
Basic operations with decimals and percent.	4	1	0
Conversion of common fractions to decimals or percent and vice versa.	4	1	0
Using percent to calculate interest, mark-up and/or discount.	5	0	0
Knowing common metric weights and measures.	4	1	0
Knowing common English weights and measures.	5	0	0
Converting English to metric weights and measures.	2	3	0
Measuring with rule or tape.	5	0	0
Measuring with micrometer.	1	4	0
Estimation of measurements, (e.g. hold electrode 1/8'' from work).	5	0	0
Reading gauges and meters.	3	2	0
Calculating ratio and/or proportion.	3	1	1
Solving ratio and proportion problems, (e.g. interpreting scale drawings).	3	2	0
Finding Powers of numbers.	1	2	2
Using mathematical tables.	1	3	1
Calculating square root.	2	2	1
Using scientific notation (powers of 10).	0	2	3
Using common logarithms to solve mathematical problems.	0	1	4
Basic operations with positive and negative numbers.	3	0	2
Basic operations with literal expressions (algebra).	1	2	2
Interpreting line and/or bar graphs.	2	1	2

TABLE XV (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
Constructing line and/or bar graphs.	0	3	2
Applying formulas (by substitution of numerical values).	5	0	0
Solving linear equations.	2	3	0
Transposing, factoring and cancellation.	2	1	2
Solving simultaneous equations.	0	2	3
Solving quadratic equations.	0	0	5
Knowing meaning of parallelism between lines and/or planes.	3	2	0
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	3	2	0
Measuring angles.	3	2	0
Laying out or adjusting angles to given number of degrees.	3	2	0
Calculating area of square or rectangle.	3	2	0
Calculating circumference and/or area of circle.	4	1	0
Finding unknown side of right triangle (Pythagorean theorem).	1	3	1
Finding area and/or volume of rectangular solids, (e.g. tanks).	5	0	0
Finding area and/or volume of cylinders.	5	0	0
Interpreting "pie" or circle graphs.	3	1	1
Constructing "pie" or circle graphs.	1	1	3
Using slide rule to solve mathematical problems.	0	4	1
Using calculator for basic operations.	0	5	0
Knowledge of set theory.	0	1	4
Completing business forms, (e.g. invoices, work orders, bills of sale).	3	2	0
Record keeping.	3	2	0
Solving vector analysis problems.	0	2	3

TABLE XVI

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES AND PERCENTAGES FOR WELDERS SAMPLE

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY		DESIRABLE		NOT NEEDED	
	NO.	%	NO.	%	NO.	%
Basic operations (+, -, x, ÷) with whole numbers.	16	100.0	0	0.0	0	0.0
Basic operation with common fractions.	16	100.0	0	0.0	0	0.0
Basic operations with decimals and percent.	11	68.8	4	25.0	1	6.3
Conversion of common fractions to decimals or percent and vice versa.	11	68.8	4	25.0	1	6.3
Using percent to calculate interest, mark-up and/or discount.	9	56.3	5	31.3	2	12.5
Knowing common metric weights and measures.	6	37.5	7	43.8	3	18.8
Knowing common English weights and measures.	16	100.0	0	0.0	0	0.0
Converting English to metric weights and measures.	3	18.8	10	62.5	3	18.8
Measuring with rule or tape.	16	100.0	0	0.0	0	0.0
Measuring with micrometer.	4	26.7	9	60.0	2	13.3
Estimation of measurements, (e.g. hold electrode 1/8" from work).	16	100.0	0	0.0	0	0.0
Reading gauges and meters.	12	75.0	4	25.0	0	0.0
Calculating ratio and/or proportion.	8	50.0	7	43.8	1	6.3
Solving ratio and proportion problems (e.g. interpreting scale drawings).	10	62.5	6	37.5	0	0.0
Finding Powers of numbers.	4	25.0	6	37.5	6	37.5
Using mathematical tables.	8	50.0	7	43.8	1	6.3
Calculating square root.	7	43.8	7	43.8	2	12.5
Using scientific notation (powers of 10).	1	6.3	8	50.0	7	43.8
Using common logarithms to solve mathematical problems.	2	12.5	6	37.5	8	50.0
Basic operations with positive and negative numbers.	8	50.0	3	18.8	5	31.3
Basic operations with literal expressions (algebra).	2	12.5	9	56.3	5	31.3
Interpreting line and/or bar graphs.	5	31.3	6	37.5	5	31.3

TABLE XVI (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY NO.	NECESSARY %	DESIRABLE NO.	DESIRABLE %	NOT NEEDED NO.	NOT NEEDED %
Constructing line and/or bar graphs.	2	12.5	9	56.3	5	31.3
Applying formulas (by substitution of numerical values).	10	62.5	4	25.0	2	12.5
Solving linear equations.	6	37.5	8	50.0	2	12.5
Transposing, factoring and cancellation.	5	31.3	5	31.3	6	37.5
Solving simultaneous equations.	0	0.0	8	50.0	8	50.0
Solving quadratic equations.	0	0.0	5	31.3	11	68.8
Knowing meaning of parallelism between lines and/or planes.	11	68.8	5	31.3	0	0.0
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	14	87.5	2	12.5	0	0.0
Measuring angles.	14	87.5	2	12.5	0	0.0
Laying out or adjusting angles to given number of degrees.	13	81.3	3	18.8	0	0.0
Calculating area of square or rectangle.	13	81.3	3	18.8	0	0.0
Calculating circumference and/or area of circle.	15	93.8	1	6.3	0	0.0
Finding unknown side of right triangle (Pythagorean theorem).	6	37.5	8	50.0	2	12.5
Find area and/or volume of rectangular solids, (e.g. tanks).	14	87.5	2	12.5	0	0.0
Finding area and/or volume of cylinders.	14	87.5	2	12.5	0	0.0
Interpreting "pie" or circle graphs.	10	62.5	4	25.0	2	12.5
Constructing "pie" or circle graphs.	8	50.0	5	31.3	3	18.8
Using slide rule to solve mathematical problems.	2	12.5	12	75.0	2	12.5
Using calculator for basic operations.	5	33.3	10	66.7	0	0.0
Knowledge of set theory.	5	33.3	4	26.7	6	40.0
Completing business forms, (e.g. invoices, work orders, bills of sale).	7	43.8	6	37.5	3	18.8
Record keeping.	8	50.0	6	37.5	2	12.5
Solving vector analysis problems.	1	6.3	6	37.5	9	56.3

Data Tabulation for Three Samples Combined

Table XVII shows mathematical knowledges and skills frequencies and percentages for 50 respondents from the three samples combined. This number includes 19 respondents from the Motor Mechanics sample, 15 respondents from the Heavy Duty Mechanics sample, and 16 respondents from the Welders sample.

TABLE XVII

MATHEMATICAL KNOWLEDGES AND SKILLS FREQUENCIES FOR PERCENTAGES FOR THREE SAMPLES COMBINED

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY		DESIRABLE		NOT NEEDED	
	NO.	%	NO.	%	NO.	%
Basic operations (+, -, x, ÷) with whole numbers.	48	96.0	1	2.0	1	2.0
Basic operation with common fractions.	47	94.0	3	6.0	0	0.0
Basic operations with decimals and percent.	41	82.0	7	14.0	2	4.0
Conversion of common fractions to decimals or percent and vice versa.	37	70.0	12	24.0	3	6.0
Using percent to calculate interest, mark-up and/or discount.	21	42.0	20	40.0	9	18.0
Knowing common metric weights and measures.	27	54.0	19	38.0	4	8.0
Knowing common English weights and measures.	45	90.0	2	4.0	3	6.0
Converting English to metric weights and measures.	22	44.0	23	46.0	5	10.0
Measuring with rule or tape.	48	96.0	2	4.0	0	0.0
Measuring with micrometer.	36	73.5	11	22.4	2	4.1
Estimation of measurements, (e.g. hold electrode 1/8" from work).	41	82.0	7	14.0	2	4.0
Reading gauges and meters.	45	90.0	5	10.0	0	0.0
Calculating ratio and/or proportion.	32	64.0	17	34.0	1	2.0
Solving ratio and proportion problems (e.g. interpreting scale drawings).	26	52.0	18	36.0	6	12.0
Finding Powers of numbers.	5	10.2	16	32.7	28	57.1
Using mathematical tables.	16	32.0	26	52.0	8	16.0
Calculating square root.	10	20.0	13	26.0	27	54.0
Using scientific notation (powers of 10).	3	6.0	15	30.0	32	64.0
Using common logarithms to solve mathematical problems.	7	14.0	10	20.0	33	66.0
Basic operations with positive and negative numbers.	17	34.0	14	28.0	19	38.0
Basic operations with literal expressions (algebra).	8	16.0	22	44.0	20	40.0
Interpreting line and/or bar graphs.	14	28.0	24	48.0	12	24.0

TABLE XVII (contd.)

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY		DESIRABLE		NOT NEEDED	
	NO.	%	NO.	%	NO.	%
Constructing line and/or bar graphs.	5	10.0	25	50.0	20	40.0
Applying formulas (by substitution of numerical values).	16	32.0	17	34.0	17	34.0
Solving linear equations.	10	20.0	17	34.0	23	46.0
Transposing, factoring and cancellation.	10	20.0	12	24.0	28	56.0
Solving simultaneous equations.	3	6.0	12	24.0	35	70.0
Solving quadratic equations.	1	2.0	10	20.0	39	78.0
Knowing meaning of parallelism between lines and/or planes.	20	40.0	17	34.0	13	26.0
Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.	35	70.0	11	22.0	4	8.0
Measuring angles.	37	74.0	13	26.0	0	0.0
Laying out or adjusting angles to given number of degrees.	35	70.0	11	22.0	4	8.0
Calculating area of square or rectangle.	28	57.1	16	37.7	5	10.2
Calculating circumference and/or area of circle.	34	68.0	12	24.0	4	8.0
Finding unknown side of right triangle (Pythagorean theorem).	8	16.0	24	48.0	18	36.0
Find area and/or volume of rectangular solids, (e.g. tanks).	28	56.0	18	36.0	4	8.0
Finding area and/or volume of cylinders.	35	70.0	12	24.0	3	6.0
Interpreting "pie" or circle graphs.	20	40.0	14	28.0	16	32.0
Constructing "pie" or circle graphs.	13	26.5	17	34.7	19	38.8
Using slide rule to solve mathematical problems.	3	6.0	32	64.0	15	30.0
Using calculator for basic operations.	6	12.2	33	67.3	10	20.4
Knowledge of set theory.	14	29.2	11	22.9	23	47.9
Completing business forms, (e.g. invoices, work orders, bills of sale).	26	52.0	19	38.0	5	10.0
Record keeping.	25	50.0	21	42.0	4	8.0
Solving vector analysis problems.	4	8.3	14	29.2	30	62.5

Comments and Mathematical Shortcuts

The research instrument used in the study included a request directed to the respondent that he write in comments or describe any mathematical shortcuts that might be used in the practice of his trade. The request for mathematical shortcuts had been included in the research instrument to identify those shortcuts that might be included as curriculum content in mathematics courses designed to meet the needs of students enrolled in vocational education courses at the high school level.

An examination of the 50 completed questionnaires returned showed that the request for comments or mathematical shortcuts had elicited 17 replies. These replies were found to be unevenly distributed among nine of the twelve sample subgroups in the study. Because of the nature of the replies and their uneven distribution among sample subgroups, it was decided to reproduce these comments verbatim rather than to attempt tabulation.

The Motor Mechanics Sample

Supervisors. The lone respondent in this category suggested "More training in metric measurement" and "Complete turn over [sic] into metric".

Journeymen, Group A. Two replies were found in this category:

1. More metrics.
2. Measuring angles is becoming more important. A practicing journeyman mechanic can do very well on secondary school level mathematics. Only if he becomes involved in his own business need he know more - i.e., record keeping, etc. The most difficult problem that most (90%) of the mechanics would encounter would be something to the effect of: If a car used .178 gal. of gasoline to travel 3 miles, how many miles to the gallon is that? Being involved in the re-

pair of a machine does not make it necessary to know the math of design.

Journeymen, Group B. The respondent in this category suggested "Require more metric conversion".

Instructors. This group produced three replies:

1. Mathematical theory, unless used, becomes stale. % [therefore] essential theory is all that is necessary.

2. The understanding of the physical world is the important part. The mathematics is a means of precise comparison that is essential for design but not necessary but desirable for the practice of the trade.

3. Auto mechanics use conversion charts for [converting] fractions to decimals and for finding volumes where possible.

The Heavy Duty Mechanics Sample

Only one reply was found among the completed questionnaires from this sample:

Journeymen, Group B. This respondent suggested: "Mathematics is necessary in the motor trade but practical [skill] is more important".

The Welders Sample

Supervisors. Three replies were received from this category of the sample:

1. Use of math, tables, %. Mr. Verret - you either know the method or you must hire someone to compute, complete and record, i.e. #41 [Using calculator for basic operations], 43 [Completing business forms], 44 [Record keeping]. When metric system becomes universal, #6 [Knowing common metric weights and measures], 8 [Converting English to metric weights and measures] are necessary.

2. Basic math. Old math.

3. Use of framing square to determine pitches, stair treads etc. Use of level for lining up frames etc. Use of protractor for determining

angles etc.

Journeymen, Group A. Three comments were found in this category:

1. This questionnaire should have been completed by a private welder rather than one who works in a shop where the greater percentage of the math is all figured out on blueprints.

2. Basic mathematics very essential.

3. You need common sense.

Journeymen, Group B. Two respondents from this category wrote in comments:

1. A basic knowledge of mathematics in all its forms is generally sufficient for shop floor practices. Shortcuts are used, but only after a lengthy period of proper work procedure has been observed, and experience gained.

2. The more knowledge a person has the more successful he will be. A certain amount of mathematical shortcuts can be learned after more experience is gotten.

Instructors. One respondent in this category provided two mathematical shortcuts used in the trade in connection with machine work:

1. $\text{R.P.M.} = \dfrac{4 \times \text{cutting speed}}{\text{Diameter of shaft or stock}}$

2. Tap drill size =

$$\text{outside diameter of bolt} - \frac{1}{\text{\# threads per inch}}$$

CHAPTER IV

PRESENTATION OF FINDINGS

The previous chapter described the populations and sampling procedure for the study and the research instrument used in the study. Also dealt with were the execution of the pilot study, the distribution of research instruments for the study, the tabulation of data collected for the study and the comments and mathematical shortcuts provided by the respondents in the study.

This chapter presents the data collected in the study in the form of compound bar histograms and proposes a method of using these histograms to design mathematics courses to meet the needs of students enrolled in high school vocational education programs.

The Histograms

The mathematical knowledges and skills frequencies for each sample were converted into percent proportions of response alternatives for each of the 45 questionnaire items. These percentages were then graphically illustrated by means of a compound bar histogram for each of the three samples, namely, the Motor Mechanic sample, the Heavy Duty Mechanic sample, and the Welder sample. A fourth compound bar histogram shows the combined percent proportions of response alternatives selected by respondents from the three samples named above.

Figure 1 shows the percent proportions of respondents from the Motor Mechanic sample who rated each mathematical knowledge and skill item as "necessary", "desirable", or "not needed" by journeymen in order that they may be able to practice their trade in a successful manner.

Figure 11 shows the percent proportions of respondents from the Heavy Duty Mechanic sample who rated each mathematical knowledge and

skill item as "necessary", "desirable", or "not needed" by journeymen in order that they may be able to practice their trade in a successful manner.

Figure 111 shows the percent proportions of respondents from the Welder sample who rated each mathematical knowledge and skill item as "necessary", "desirable", or "not needed" by journeymen in order that they may be able to practice their trade in a successful manner.

Figure 1V shows the combined percent proportions of respondents from the Motor Mechanic sample; the Heavy Duty Mechanic sample and the Welder sample who rated each mathematical knowledge and skill item as "necessary", "desirable", or "not needed" by journeymen in order that they may be able to practice their respective trades in a successful manner.

The percent proportions of respondents who rated each mathematical competency item as "necessary" are represented by a line pattern at the left-hand end of each compound bar. The percent proportions of respondents who rated each mathematical competency item as "not needed" are represented by an unpatterned segment situated at the right-hand end of each compound bar. The percent proportion of respondents who rated mathematical competency items as "desirable" are represented by a random dot pattern situated between the other two segments of each compound bar.

Percent figures shown on the compound bar segments have been rounded off to the nearest 0.1 percent. For this reason all triads of percent figures may not total exactly 100.0 percent.

FIGURE 1

MATHEMATICAL KNOWLEDGES AND SKILLS PERCENTAGES
FOR MOTOR MECHANICS

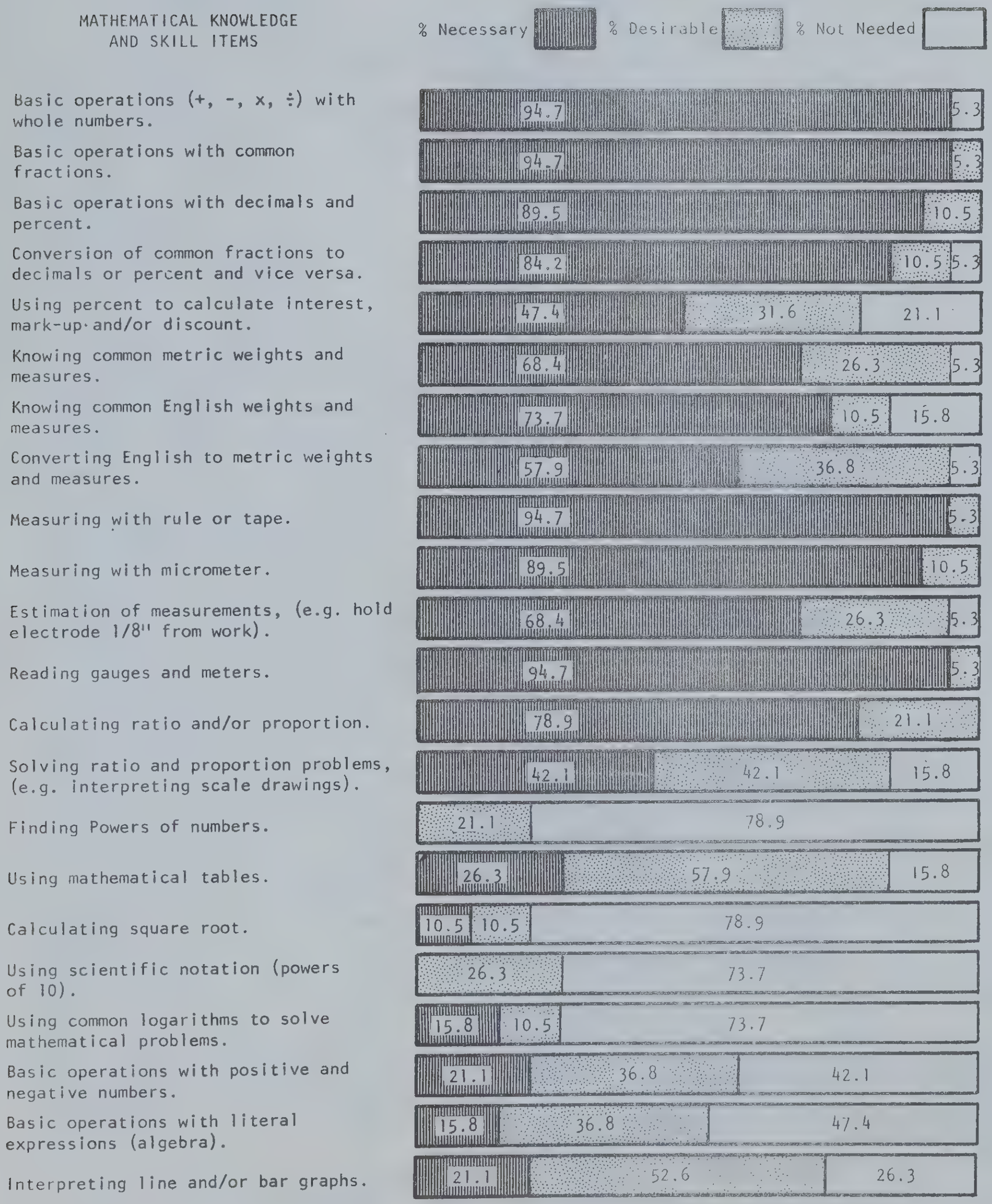


FIGURE 1 (contd.)

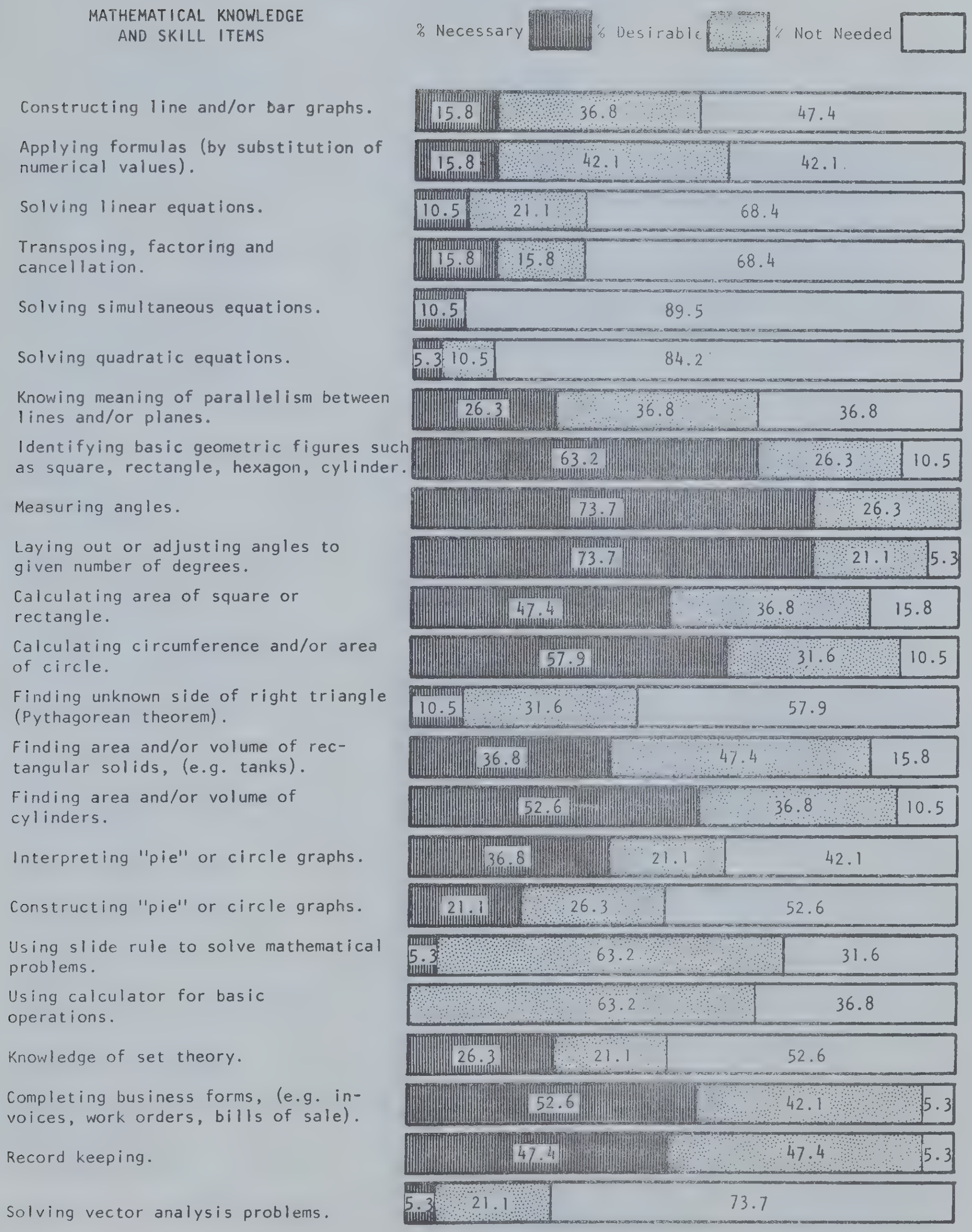


FIGURE 2

MATHEMATICAL KNOWLEDGES AND SKILLS PERCENTAGES
FOR HEAVY DUTY MECHANICS

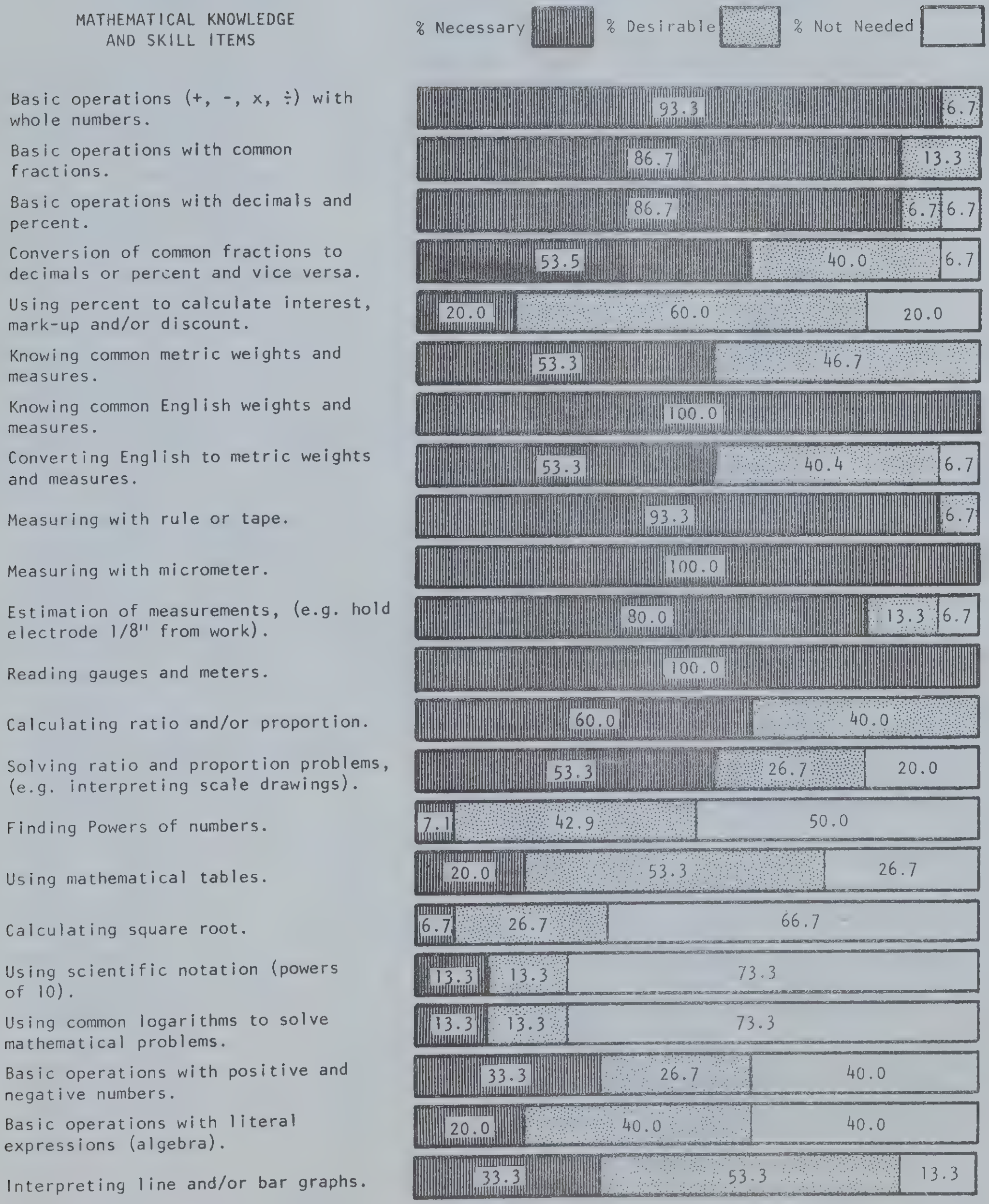


FIGURE 2 (contd.)

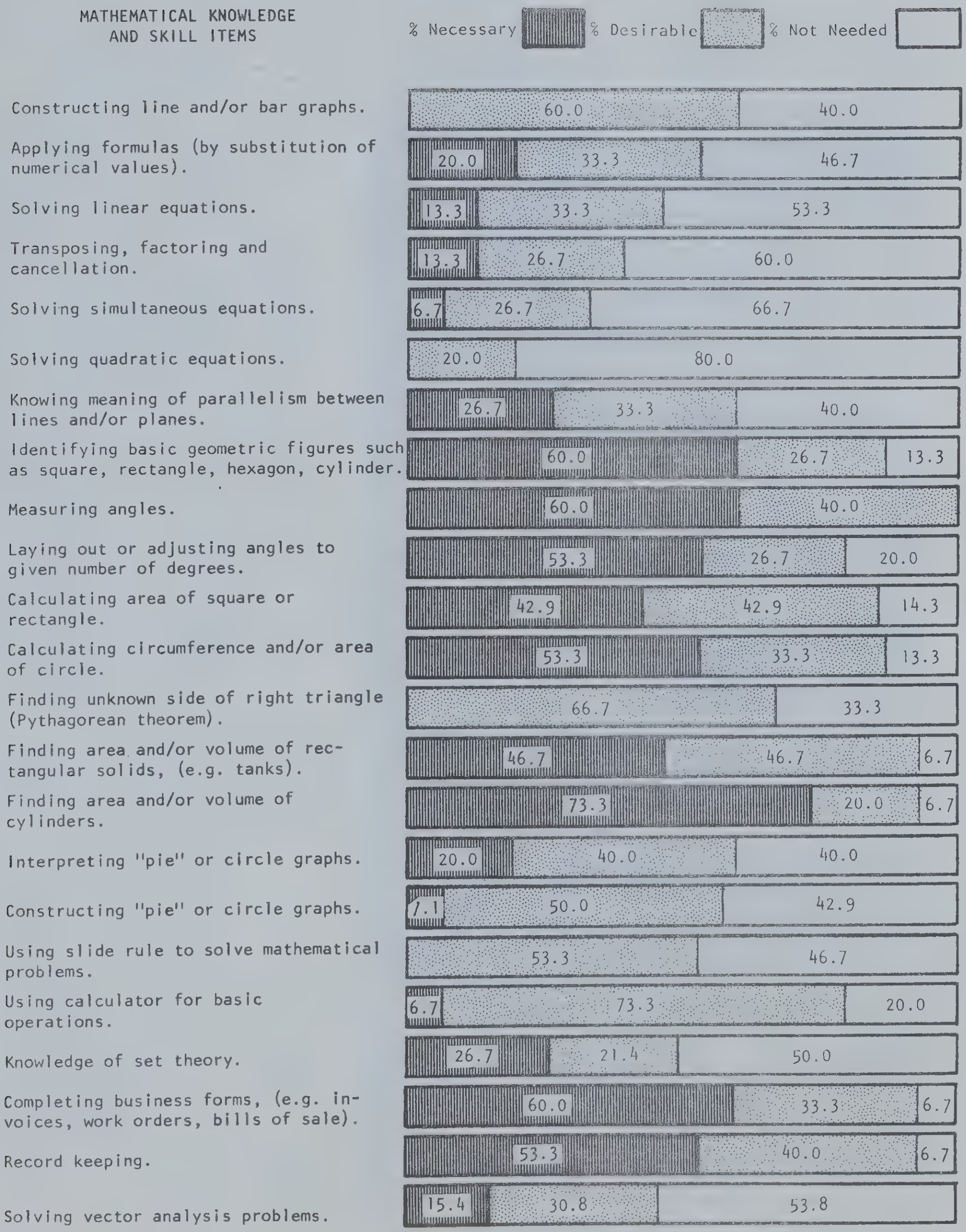


FIGURE 3

MATHEMATICAL KNOWLEDGES AND SKILLS PERCENTAGES FOR WELDERS

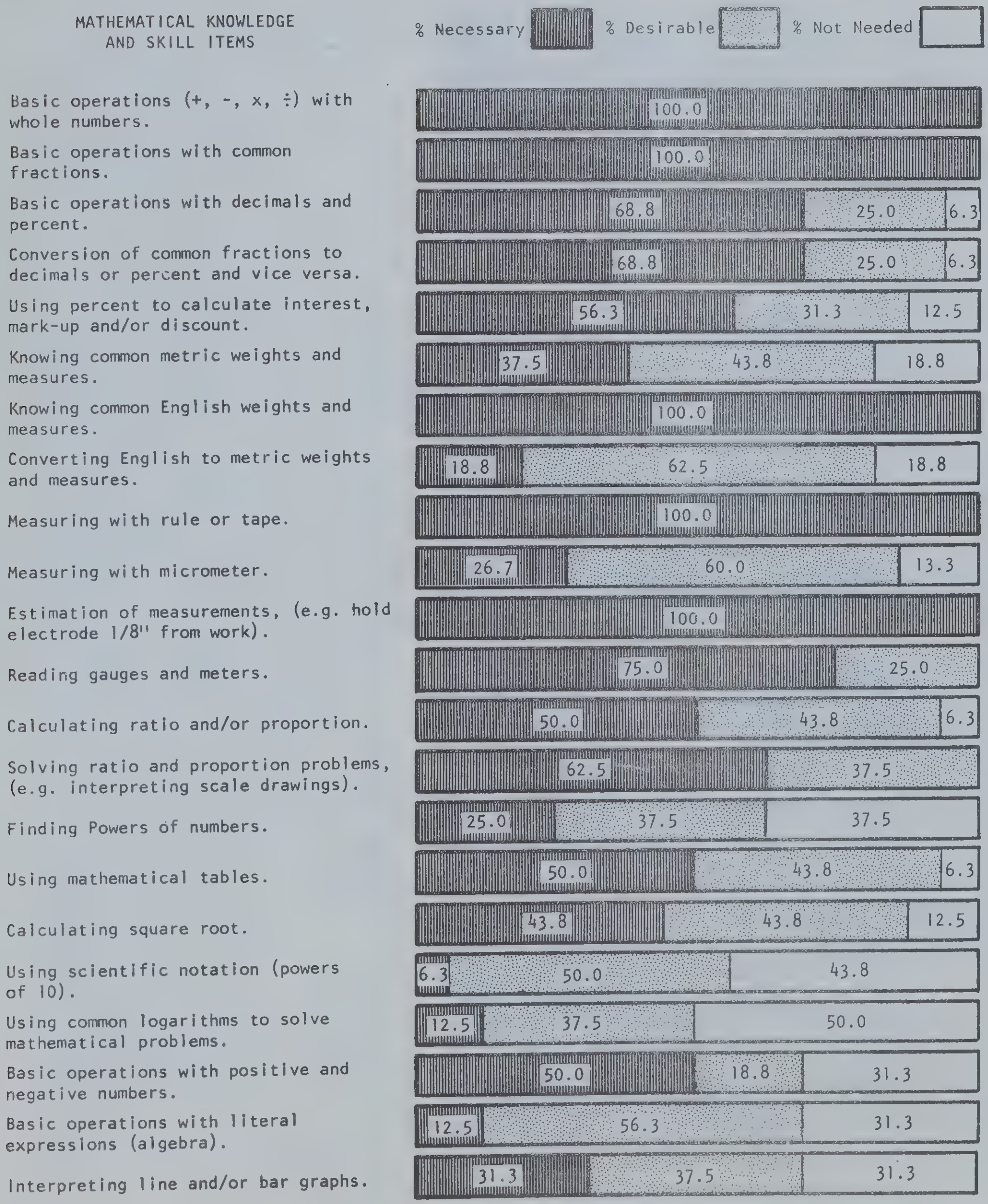


FIGURE 3 (contd.)

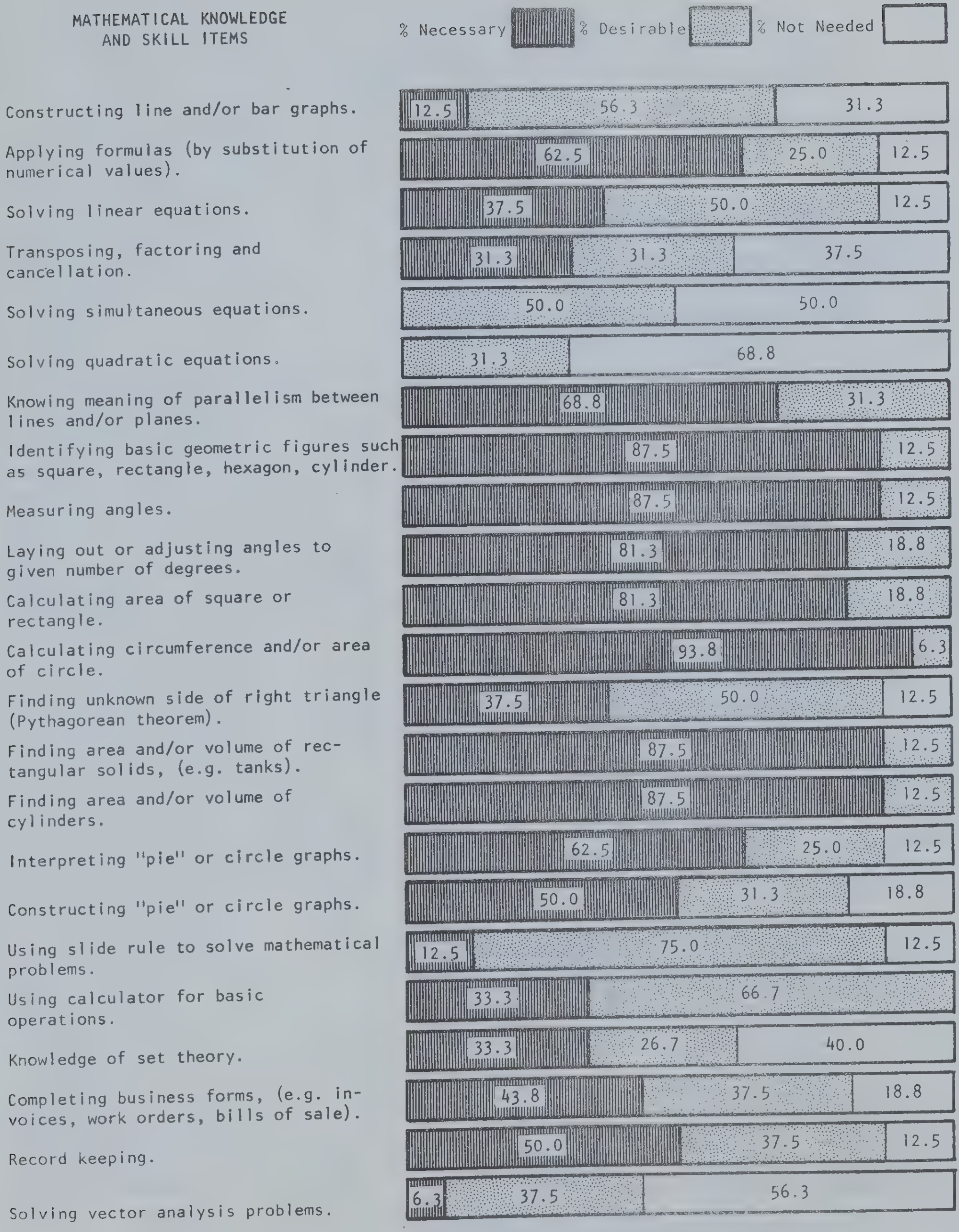


FIGURE 4

MATHEMATICAL KNOWLEDGES AND SKILLS PERCENTAGES FOR MOTOR MECHANICS, HEAVY DUTY MECHANICS AND WELDERS COMBINED

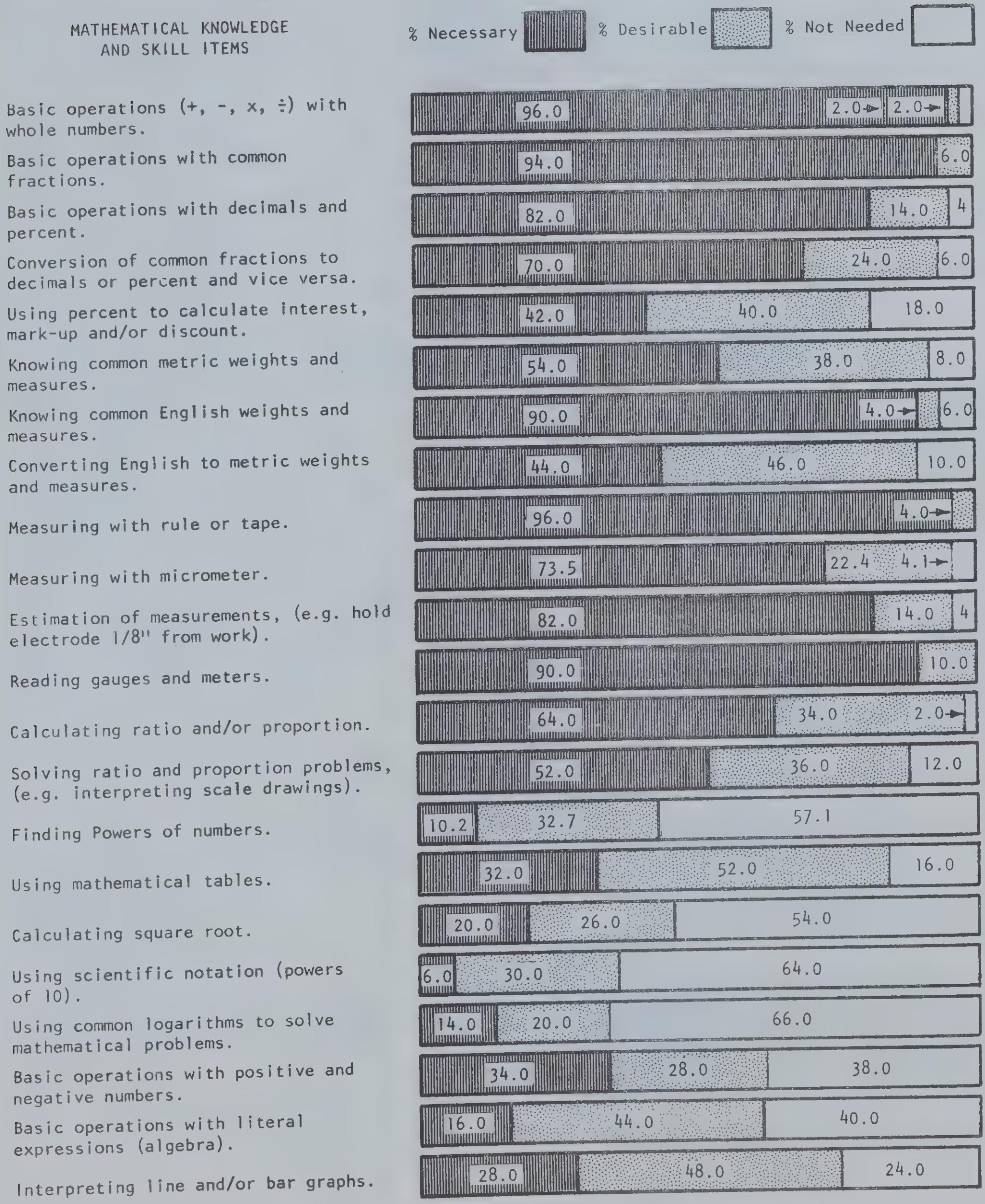
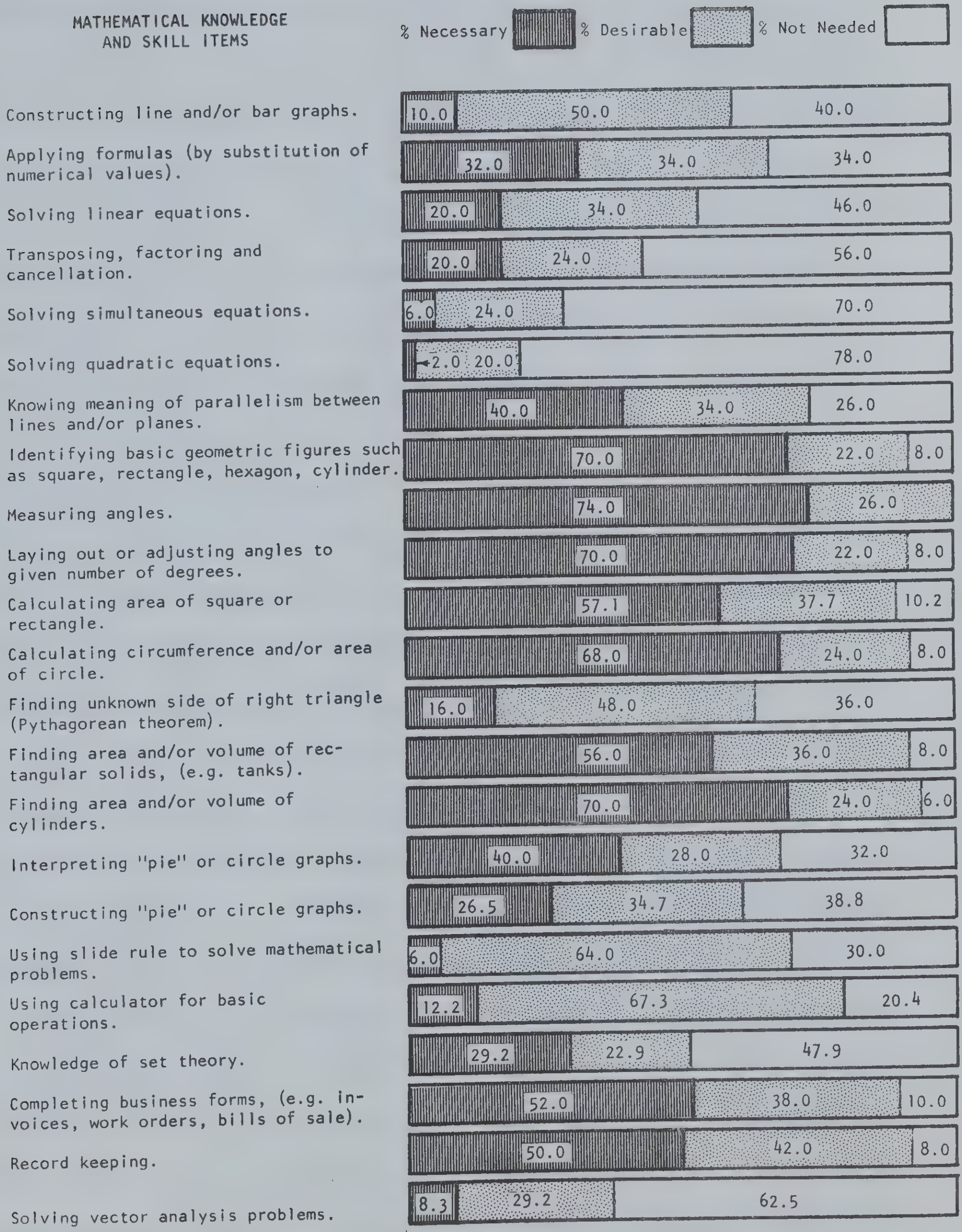


FIGURE 4 (contd.)



Proposed Uses of Histograms

The compound bar histograms showing the proportion of respondents who rated each mathematical knowledge and skill item as "necessary", "desirable", or "not needed" were provided for the purpose of serving as a convenient method of reference which curriculum workers may use in the design of mathematics courses whose objectives meet the needs of students in Automotives and Welding. The information represented by the histograms may be used by mathematics curriculum workers to assist them in making curriculum content decisions, in establishing curricular priorities, in designing diagnostic tests and in devising ways to improve student motivation.

Mathematics Curriculum Content

The histograms presented in this study can be used as a means of developing curriculum content for mathematics courses by identifying the mathematical functions which are important to each of three trades which correspond to the high school vocational education subjects of Automotives and Welding. The curriculum content of a given course may be developed to meet the mathematical needs of only one high school vocational education subject or of two or more vocational education subjects combined. The decision to include a particular mathematical knowledge and skill item in a course curriculum can be governed by a criterion such as selection as "necessary" by 50 percent or more of respondents from one of the sample, or from two or more samples combined. Another possible criterion might be selection of a mathematical competency item as "necessary" or "desirable" by two thirds or more of the respondents from one of the samples, or from two or more of the samples combined.

Establishing Curricular Priorities

The mathematics histograms present information in a form which can be conveniently used to help establish priorities among mathematical competencies to be included in mathematics course curricula. For instance, it might be reasonable to suppose that a mathematical competency such as "measuring with rule or tape" which was selected as "necessary" by 100 percent of the respondents from the Welder sample might be given a higher priority than "record keeping" which was rated as "necessary" by only 50 percent of these same respondents.

Diagnostic Tests

The mathematical knowledge and skill histograms developed in this study may be used to help design tests which would identify the mathematical weaknesses of students enrolled in the vocational education courses of Automotives and Welding. These results would indicate the mathematical competency areas where students may need remedial help in mathematics as it applies to their particular vocational education subject.

Student Motivation

The mathematical knowledge and skill histograms developed in this study could provide information to teachers for use in motivating students by showing them that certain mathematical knowledges and skills are important to the particular vocational education course they have chosen. The fact that the information came from journeymen certificated in trades which corresponded to high school vocational education programs might lend it greater credibility in the eyes of students than would be the case had the information originated from other sources.

CHAPTER V

SUMMARY, CONCLUSIONS, OBSERVATIONS, AND IMPLICATIONS

Chapter I dealt with the need for the study, the purpose of the study, the limitations and delimitations of the study, the significance of the study, and the definitions of terms used in the study. The chapter also included descriptions of the populations for the study, the sampling procedure used in the study, and the methodology of the study.

The second chapter of the study consisted of a review of the related literature which dealt with the academic foundation and content of occupations and, more particularly, the mathematical requirements of the three selected trades of Motor Mechanic, Heavy Duty Mechanic, and Welder. Comments on mathematics education and evaluations of mathematics programs were reviewed as were purposes of mathematics and objectives of mathematics instruction. A number of textbooks and other references related to the above three trades were analyzed for their mathematical content.

Chapter III included descriptions of the populations and of the sampling procedure for the study. The chapter also dealt with the design of the research instrument, the execution of the pilot study, the distribution of the research instruments and concluded with the tabulation of data.

Chapter IV presented the results of the study in the form of compound bar histograms which graphically illustrated the percentages of respondents who selected each of the three possible responses for each of the 45 mathematical knowledge and skill items contained in the research instrument.

Summary of the Study

The Problem

The enactment of the Technical and Vocational Training Act of 1960 opened the way for the provinces to enter into agreements with the Government of Canada whereby the Provinces obtain financial assistance for the implementation of programs of technical and vocational training.

Alberta, in 1961, entered into such an agreement and the massive building program which ensued resulted in the opening, in the fall of 1963, of vocational high schools in the larger population centres of the province.

The new schools were organized as comprehensive high schools which offered, in addition to vocational education subjects, a broad range of programs which included academic university-matriculation, general non-matriculation, as well as a wide choice of optional subjects. Students enrolled in vocational education subjects devoted approximately one half of their school time to the study of academic or general education subjects that were needed to complete the requirements for the Alberta High School Diploma.

The academic and general education subjects offered to students enrolled in high school vocational education programs were seen to hold a very important position in relation to the vocational education subjects. This was due to the fact that a number of vocational subjects, expecially those which corresponded to the skilled trades, had part of their theoretical base in the academic disciplines, notably, the mathematics and the physical sciences. In this context, these academic disciplines were referred to by Kidd and Leighbody (1955) as "related subjects" (pp. 183 - 184).

The related subject that seemed to arouse the most concern on the part of educators was mathematics. There did not appear to be sufficient information available on exactly what mathematical knowledges and skills would serve the purpose for given trades. Nelson and Halfin (1976) addressing themselves to the problem of obtaining information for the purpose of curriculum development stressed the need for direct approaches as opposed to the commonly used indirect or discipline approach (pp. 246 - 248).

The Methodology

The study was designed to collect data relating to the mathematical skills which certificated journeymen considered necessary to possess in order that they may be able to practice in a successful manner the trades of Motor Mechanic, Heavy Duty Mechanic and Welder.

The populations for the study consisted of three discrete groups of certificated journeymen. One population consisted of journeymen certificated in the Motor Mechanic trade; the second population was made up of journeymen certificated in the Heavy Duty Mechanic trade; the third population was comprised of journeymen certificated in the Welder trade. Each of these three populations was stratified as to the function performed by the journeymen. These functions were placed into the following three categories: Supervisors; Journeymen; Instructors.

A two-stage sampling procedure was used for the "Supervisors" and "Journeymen" categories of each of the three populations. Simple random sampling without replacement was used for the "Instructor" group of each of the three populations. In its final form each of the three samples was comprised of 5 "Supervisors", 10 "Journeymen", and 5 "Instructors" giving a total of 60 subjects in all for the three samples.

The research instrument for the study was a questionnaire in the form of a 45-item mathematical checkoff list similar in structure to the one used by Laws (1966) in his study on the subject of mathematical competencies for technicians. Respondents were asked to rate each mathematical knowledge and skill item on a 3-point Likert-type scale.

A pilot study was carried out in order to point up any errors or inadequacies that might have been present in the instrument. Minor modifications were made to the instrument as a result of analysis of pilot study returns.

The modified questionnaires were delivered or posted to the sample subjects. Of the 60 research instruments distributed 50 completed questionnaires were received from respondents. This represented a return rate of 83.3 percent. The results from these questionnaires were tabulated by sample subgroup. The frequencies for each item response were converted into percent proportions for each of the three samples. This approach was described by Dixon (1969, p. 9). These proportions were then graphically illustrated by means of compound bars as described by Lockwood (1969, p. 28).

The Findings Related to the Motor Mechanics Sample

Eighteen mathematical knowledge and skill items were selected as "necessary" by 50 percent or more of the Motor Mechanics sample subjects who completed and returned research instruments. These included basic operations with whole numbers, common fractions, decimals and percent; conversion of fractions to decimals; knowledge of common metric and English weights and measures and conversions; measuring with rule, tape, and micrometer; estimating measurements; measuring, laying out, or adjusting angles; calculating circumference and/or area of circle;

finding area and/or volume of cylinders and completing business forms.

The Findings Related to the Heavy Duty Mechanics Sample

Twenty mathematical knowledge and skill items were selected as "necessary" by 50 percent or more of the Heavy Duty Mechanics sample subjects who completed and returned their questionnaires. The selected items included basic operations with whole numbers, common fractions, decimals and percent; conversion of fractions to decimals; knowledge of common metric and English units of weight and measure and conversions; measuring with rule, tape and micrometer; estimation of measurements; reading gauges and meters; calculation ratio and/or proportion and solving ratio and proportion problems; identifying basic geometric figures; measuring, laying out or adjusting angles; calculation of circumference and/or area of circle; finding area and/or volume of cylinders; completing business forms and record keeping.

The Findings Related to the Welders Sample

Twenty-five mathematical knowledge and skill items were selected as "necessary" by 50 percent or more of the respondents in the Welder sample. Included in this number were basic operations with whole numbers, fractions, decimals and percent, and positive and negative numbers; conversion of fractions to decimals; using percent to calculate interest, etc.; knowing common English weights and measures; measuring with rule or tape measure; estimating measurements; reading gauges and meters; calculating ratio and/or proportion and solving ratio and proportion problems; using mathematical tables; applying formulas; knowing meaning of parallelism; identifying basic geometric figures; measuring, laying out or adjusting angles; calculating area of square or rectangle; calculating circumference and/or area of circle; finding area

and/or volume of rectangular solids and cylinders; interpreting and constructing circle graphs; record keeping.

Conclusions

The study presented data which showed that a number of basic mathematical knowledges and skills were necessary for journeymen to possess in order to enable them to practice successfully each of the three selected trades of Motor Mechanic, Heavy Duty Mechanic, and Welder. Fourteen mathematical knowledge and skill items were selected as "necessary" by 50 percent or more of the respondents in all three samples. These included basic operations with whole numbers, fractions, decimals and percent; conversion of common fractions to decimals; knowing common English weights and measures; measuring with rule or tape; estimation of measurements; reading gauges and meters; calculating ratio and/or proportion; identifying basic geometric figures; measuring, laying out, or adjusting angles; calculating circumference and/or area of circle; finding area and/or volume of cylinders.

Observations

A comparison of the findings related to the three selected trades of Motor Mechanic, Heavy Duty Mechanic and Welder showed that the Welder sample respondents had selected the greatest number of mathematical knowledge and skill items as being "necessary" for journeymen to possess in order that they may be able to practice their trade in a successful manner. A review of textbooks and other trade references for the three selected trades had shown that the references for the Welder trade had the lowest incidence of mathematical content among the three trades. This finding would seem to support Nelson and Halfin (1976) in their statement that direct approaches to curriculum design yield results

which are different from those obtained by using indirect or discipline approaches (pp. 246 - 248).

One item which drew a number of comments was "knowing common metric weights and measures". Canada has been in the process of converting to the SI [Système International d'Unités] metric system of weights and measures and it would appear that the three selected trades of Motor Mechanic, Heavy Duty Mechanic, and Welder were not uniformly affected by this change.

Among the three samples, respondents from the Motor Mechanics sample showed the highest proportion (68.4 percent) of selection of "Knowing common metric weights and measures" as being "necessary" for a journeyman to possess in order that he may be able to practice his trade in a successful manner. This may be attributed to the fact that automobiles originating from countries which use the metric system have been imported into Canada for many years. Three of the respondents who were employees of an employing agency which dealt exclusively in metric products thought that knowledge of metric weights and measures was "necessary" and that knowledge of English weights and measures was "not needed".

Respondents from the Heavy Duty Mechanics sample showed the second highest proportion (53.3 percent) of selection of "Knowing common metric weights and measures" as being "necessary" for a journeyman to possess in order that he may be able to practice his trade in a successful manner. This finding is perhaps related to the fact that Diesel engines and other items of heavy equipment have a longer life expectancy than do automobiles. Also, manufacturers of this type of equipment are perhaps finding it more difficult to convert to metric measurements. The owner

of a small Diesel engine repair shop stated that some Diesel engines from Great Britain are still not metricated. This owner also stated that since metric replacement parts are often not available, some components have to be rethreaded to English sizes to take studs or bolts which are available in Canada.

The questionnaire item "Knowing common metric weights and measures" was selected as "necessary" for journeymen to possess by 37.5 percent of respondents from the Welders sample. This low rate of selection may be partly explained by a conversation which the researcher had with a welding shop owner-manager who participated in the study. According to this supervisor, the Welder trade has not, as yet, been greatly affected by metric conversion. This supervisor related an incident which involved hydraulic truck hoists built to metric standards in Great Britain. These hoists could not be used because hose and pipe fittings which were standard in Canada would not fit the threaded openings. The British manufacturer was asked to ship only hoists with English type threads.

Implications and Recommendations

Implications for Educational Practice

This study reveals evidence which shows that a sizeable proportion of the 45 mathematical knowledges and skills listed in the research instrument were considered by respondents to be necessary for journeymen to possess in order that they may be able to engage in the successful practice of the trades of Motor Mechanic, Heavy Duty Mechanic, and Welder. An educational implication of this finding might be that students enrolled in high school vocational education courses in Automotives and Welding which correspond to the skilled trades of Motor Mechanic, Heavy Duty Mechanic and Welder should have the opportunity to

learn the kinds of mathematical competencies which will be useful to them in their subsequent apprenticeship training and in their work as certificated journeymen. This means that special related mathematics courses may have to be designed for students enrolled in the high school vocational education programs in Automotives and Welding. These related mathematics courses would then become a vehicle for infusing the identified mathematical knowledges and skills into the high school programs of study. A corollary to this implication might be that teachers of high school vocational education programs in Automotives and Welding should make provision for the reinforcement of the identified mathematical competencies in both the theoretical and practical phases of their instructional programs.

Recommendations for Further Research

Some possible areas for further research are suggested by the findings of this study:

1. Studies could be undertaken to identify mathematical competencies relating to other skilled trades which correspond to existing or projected high school vocational education courses. This information could then be used in the design of mathematics courses which specifically meet the needs of students enrolled in those high school vocational education programs of study.

2. Mathematical competency requirements could be compared for a number of skilled trades with a view to developing mathematics courses which would meet the requirements of two or more vocational education subjects in common. This method of combining related subject curriculum content for two or more vocational education courses was described by Larson (1972) who referred to it as the "core cluster approach" (p. 27).

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS - PUBLISHED WORKS

BLACK, P. Audel's Diesel Engine Manual. Indianapolis: Howard W. Sams and Co., Inc., 1966.

BLOOM, B. Taxonomy of Educational Objectives, Handbook 1: Cognitive Domain. New York: David McKay Co., Inc., 1956.

CROUSE, W. Automotive Mechanics (seventh edition). New York: McGraw-Hill Book Company, 1975.

DIXON, W., MASSEY, F. Introduction to Statistical Analysis (third edition). New York: McGraw-Hill Book Company, 1969.

GRIFFITHS, H., HOWSON, A. Mathematics, Society and Curricula. London: Cambridge University Press, 1974.

HARDING, R. The Objectives of Mathematics Education in Secondary Schools. Ann Arbor: University Microfilms, 1968.

INTERNATIONAL LABOUR OFFICE. T. & D. Abstracts. Geneva: 13, 1975.

KAPLAN, A. The Conduct of Inquiry. San Francisco: Chandler Publishing Company, 1964.

KATES, E. Diesel and High-Compression Gas Engine Fundamentals. Chicago: American Technical Society, 1965.

KIDD, D., LEIGHBODY, G. Methods of Teaching Shop and Related Subjects. Albany: Delmar Publisher, Inc., 1955.

LARSON, M. Teaching Related Subjects in Trade and Industrial and Technical Education. Columbus: Charles E. Merrill Publishing Company, 1972.

LOCKWOOD, A. Diagrams. New York: Watson-Guptill Publications, 1969.

MASSON, F. Welding Theory and Practice. Toronto: The MacMillan Company of Canada Limited, 1967.

NASH, F., BANITZ, K. Automotive Technology. Toronto: McGraw-Hill Ryerson Limited, 1973.

PENDER, J. Welding. Toronto: McGraw-Hill Company of Canada Limited, 1968.

PETERSON, J., PETERSON, M. Career Education and Mathematics. Boston: Houghton Mifflin Company, 1975.

RAJ, D. The Design of Sample Surveys. New York: McGraw-Hill Book Company, 1972.

REKTORYS, K. A Survey of Applicable Mathematics. Cambridge: Massachusetts Institute of Technology Press. 1969.

RHODES, J. Alternative to a Decadent Society. Indianapolis: Howard W. Sams Co., Inc., 1969.

SELTITZ, C., JAHODA, M., DEUTSCH, M., COOK, S. Research Methods in Social Relations. New York: Holt, Rinehart and Winston, 1967.

SMITH, B., STANLEY, W., SHORES, J. Fundamentals of Curriculum Development. New York: World Book Company, 1957.

STOCKEL, M. Auto Mechanics Fundamentals. South Holland: Goodheart - Willcox Company, Inc., 1976.

TRAVERS, K. Forced-Choice Preferences for Problem-Solving Situations in Mathematics (Doctoral dissertation, University of Illinois, 1965). Dissertation Abstracts, 26, 1966, pp. 7161 - 7162. (University Microfilms No. 66-4310).

ZEIZEL, H. Say It With Figures. New York: Harper and Row Publishers, 1968.

B. GOVERNMENT PUBLICATIONS

ALBERTA ADVANCED EDUCATION AND MANPOWER. Apprenticeship Training. Heavy Duty Program 1973. Edmonton, 1973.

ALBERTA ADVANCED EDUCATION AND MANPOWER. Apprenticeship Training. Motor Mechanic Program 1974. Edmonton, 1974.

ALBERTA ADVANCED EDUCATION AND MANPOWER. Apprenticeship Training. Welder Program 1973. Edmonton, 1973.

ALBERTA DEPARTMENT OF EDUCATION. Curriculum Guide to Mathematics 10, 13, 20, 23, 30, 33. Edmonton: Queen's Printer, 1971.

ALBERTA DEPARTMENT OF EDUCATION. Junior-Senior High School Handbook 1976-77. Edmonton: Queen's Printer, 1976.

ALBERTA DEPARTMENT OF EDUCATION. Revision of the High School Mathematics Curriculum. Edmonton: Curriculum Branch, 1970.

ALBERTA DEPARTMENT OF EDUCATION. Senior High School Curriculum Guide for Mathematics. Edmonton: Queen's Printer, 1959.

ALBERTA DEPARTMENT OF EDUCATION. Senior High School Curriculum Guide for Mathematics. Edmonton: Queen's Printer, 1963.

ALBERTA MANPOWER AND LABOUR. Apprenticeship Opportunities. Edmonton: Queen's Printer, 1973.

ALBERTA MANPOWER AND LABOUR. Motor Mechanic Trade. Edmonton: Queen's Printer, 1974.

BRITISH COLUMBIA DEPARTMENT OF LABOUR. The British Columbia Apprenticeship Training Program. British Columbia: Division of Post-Secondary Education.

CANADA DEPARTMENT OF LABOUR. A Modern Concept of Apprenticeship: The Story of Apprenticeship in Alberta. Ottawa: Queen's Printer, 1957.

COHEN, P. Recent Development in Public Technical and Vocational Education in Canada. Canada Yearbook 1963-64. Ottawa: Queen's Printer, 1964, pp. 734 - 743.

EDMONTON TELEPHONES. Edmonton and Vicinity Yellow Pages. Edmonton: Bulletin-Commercial Printers Limited, 1976.

EDUCATIONAL RESEARCH COUNCIL OF GREATER CLEVELAND. Greater Cleveland Mathematics Program. Chicago: Science Research Associates, 1965.

GOVERNMENT OF CANADA. Statutes of Canada, 1960-61. Ottawa: Queen's Printer, 1961.

OREGON STATE DEPARTMENT OF EDUCATION. The Oregon Vo-Tech Mathematics Project, Final Report. Salem: Linn-Benten Community College, Albany Oregon, 1975.

SECONDARY SCHOOL MATHEMATICS AD HOC COMMITTEE. Survey of Senior High School Mathematics. Edmonton: Alberta Education Curriculum Branch, 1975.

SMITH, A. Generic Skills for Occupational Training. Saskatoon: Saskatchewan, New Start, 1973.

UNITED STATES OFFICE OF EDUCATION. Diesel Servicing. Washington: United States Government Printing Office, 1969.

UNITED STATES OFFICE OF EDUCATION. Education for a Changing World of Work. Washington: United States Government Printing Office, 1963.

UNITED STATES OFFICE OF EDUCATION. Education for a Changing World of Work. Washington: United States Government Printing Office, 1964.

C. PERIODICALS

ARNSTEIN, G. The Technological Context of Vocational Education. In M. Barlow (Editor), Vocational Education. Chicago: The University of Chicago Press, 1965, pp. 39 - 63.

BOWEN, J. Mathematics and the Teaching of Science. The Mathematics Teacher, 56, 6, October, 1966, pp. 536 - 542.

BROWN, G., KINNEY. L. Let Us Look Again at General Mathematics. School, Science and Mathematics, 75, 7, November, 1975, pp. 615 - 620.

CARLTON, C. Mathematics in the Skilled Trades. The Mathematics Teacher, 46, 1, January, 1953, pp. 8 - 13, 27.

CARMICHAEL, R. The Larger Human Worth of Mathematics. The Scientific Monthly, 14, May, 1922, pp. 447 - 468.

CHESNEY, J. The Working World and What It's All About. Business Reporter, 53, October 14, 1976.

FARNSWORTH, L. Modern Mathematics and Further Education: A Cause for Concern. Mathematics in School, 5, 5, November, 1976, p. 26.

FAWCETT, H. Reflections of a Retiring Teacher of Mathematics. The Mathematics Teacher, 57, 7, November, 1964, pp. 450 - 456.

FITZGERALD, A. School Mathematics and the Requirements of Industry. The Vocational Aspect of Education, 28, 70, Summer, 1976, pp. 43 - 49.

JOHNSON, B. Conversations with Business and Industry. American Vocational Journal, 46, 5, May, 1971, pp. 59 - 61.

JUDKINS, P. Applied Mathematics in High School. The Mathematics Teacher, 35, 6, October, 1942, pp. 260 - 264.

KAPUR, J. Culture, Excitement, and Relevance of Mathematics. Mathematical Education, 7, u, May 1976, pp. 161 - 180.

KLINE, M. The Ancients Versus the Moderns, a New Battle of the Books. The Mathematics Teacher, 51, 6, October, 1958, pp. 418 - 427.

MALLINSON, G. I Had It But Its All Gone Now! School, Science, and Mathematics, 74, 7, November, 1974, pp. 557 - 558.

MEULLER, F. The Revolution of Sputnik Plus Ten. The Mathematics Teacher, 50, 7, November, 1967, pp. 696 - 706.

NELSON, O., HALFIN, H. A Practical Curriculum Development System. Man/Society/Technology, 35, 8, May-June, 1976, pp. 246 - 248.

NEW MATH JUST DOESN'T ADD UP. Edmonton Journal, July 19, 1976, p. 1.

NORTHROP, E. Modern Mathematics and the Secondary School Curriculum. The Mathematics Teacher, 48, 8, 1955, pp. 386 - 393.

OLSON, A., FREEMAN, E. The Objectives for Teaching Mathematics in the Junior High School as Perceived by Parents, Students, Teachers and Professionsl Educators. The Alberta Journal of Educational Research, 22, 1, March 1976, pp. 52 - 58.

PIKE, D. Modern Mathematics and Further Education: The Views of College Lectures. Mathematics in School, 5, 5, November, 1976, pp. 27 - 28.

PRIESTLY, E. A Conflict Between Theoretical and Computational Mathematics. The Mathematics Teacher, 40, 1, January, 1947, pp. 24 - 26.

RAPPAPORT, E. The New Math and Its Aftermath. The Education Digest, 42, 5, May, 1976, pp. 6 - 9.

REYS, R. Consumer Math: Just How Knowledgeable Are U. S. Young Adults? Phi Delta Kappan, 58, 3, November, 1976.

ROTHE, C. Mathematics as Applied to apprenticeship in Trades. The Mathematics Teacher, 35, 1, January, 1942, pp. 29 - 32.

SMITH, D. Certain Mathematical Ideals of the Junior High School. The Mathematics Teacher, 14, 3, March, 1921, pp. 124 - 127.

THE VALEDICTORIAN in Newsweek, 88, 10, September 6, 1976, p. 52.

WERREMEYER, D. Computation in Junior High School Mathematics. The Mathematics Teacher, 14, 6, October, 1921, pp. 255 - 260.

WILSON, J. Mathematics: A Must for the Mechanic. The Mathematics Teacher, 45, 1, January 1952, p. 27.

WORTH, W. Education at the Crossroads. The A. T. A. Magazine, 44, 6, February 1964, pp. 6 - 13.

ZAHORIK, J. The Virtue of Vagueness in Instructional Objectives. The Elementary School Journal, 76, 7, April, 1976, pp. 411 - 419.

D. UNPUBLISHED MATERIALS

BROAD, T. A Systems Model for Apprenticeship Training. Unpublished master's thesis, University of Alberta, 1972.

KENNEDY, G. The Development of a Handbook for Welding Theory. Unpublished master's thesis, University of Alberta, 1972.

LAWS, N. Mathematical Expectations of Technicians in Michigan Industries. Lansing: Department of Public Instruction, Vocational Division, 1966.

NIELSON, H. Vocational Students on Apprenticeship. Unpublished master's thesis, University of Alberta, 1973.

APPENDIX A

Appendix A consists of the research instrument used in the study.

MATHEMATICAL SKILLS QUESTIONNAIRE

Name of firm or employer ______________________________

Trade (check one):
_____ Motor Mechanic
_____ Heavy Duty Mechanic
_____ Welder

Type of employment:
_____ Practicing journeyman (5 years experience or less)
_____ Practicing journeyman (more than 5 years experience)
_____ Supervisor
_____ Instructor

Directions: Please rate each mathematical knowledge or skill item as to how important you think it is to a journeyman for successful performance in the trade. When you have decided, place a check mark in the "NECESSARY", "DESIRABLE", or "NOT NEEDED" column on the right hand side of the questionnaire.

NOTE: Please be sure to rate and mark all items.

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
1. Basic operations (+, -, x, ÷) with whole numbers.			
2. Basic operations with common fractions.			
3. Basic operations with decimals and percent.			
4. Conversion of common fractions to decimals or percent and vice versa.			
5. Using percent to calculate interest, mark-up, and/or discount.			
6. Knowing common metric weights and measures.			

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
7. Knowing common English weights and measures.			
8. Converting English to metric weights and measures.			
9. Measuring with rule or tape measure.			
10. Measuring with micrometer.			
11. Estimation of measurements, (e.g. hold electrode 1/8" from work).			
12. Reading gauges and meters.			
13. Calculating ratio and/or proportion.			
14. Solving ratio and proportion problems, (e.g. interpreting scale drawings).			
15. Finding powers of numbers.			
16. Using mathematical tables.			
17. Calculating square root.			
18. Using scientific notation (powers of 10).			
19. Using common logarithms to solve mathematical problems.			
20. Basic operations with positive and negative numbers.			

MATHEMATICAL KNOWLEDGE AND SKILL ITEMS		NECESSARY	DESIRABLE	NOT NEEDED
21.	Basic operations with literal expressions (algebra).			
22.	Interpreting line and/or bar graphs.			
23.	Constructing line and/or bar graphs.			
24.	Applying formulas (by substitution of numerical values).			
25.	Solving linear equations.			
26.	Transposing, factoring and cancellation.			
27.	Solving simultaneous equations.			
28.	Solving quadratic equations.			
29.	Knowing meaning of parallellism between lines and/or planes.			
30.	Identifying basic geometric figures such as square, rectangle, hexagon, cylinder.			
31.	Measuring angles.			
32.	Laying out or adjusting angles to given number of degrees.			
33.	Calculating area of square or rectangle.			
34.	Calculating circumrerence and/or area of circle.			
35.	Finding unknown side of right triangle (Pythagorean theorem).			

	MATHEMATICAL KNOWLEDGE AND SKILL ITEMS	NECESSARY	DESIRABLE	NOT NEEDED
36.	Finding area and/or volume or rectangular solids, (e.g. tanks).			
37.	Finding area and/or volume of cylinders.			
38.	Interpreting "pie" or circle graphs.			
39.	Constructing "pie" or circle graphs.			
40.	Using slide rule to solve mathematical problems.			
41.	Using calculator for basic operations.			
42.	Knowledge of set theory.			
43.	Completing business forms, (e.g. invoices, work orders, bills of sale).			
44.	Record keeping.			
45.	Solving vector analysis problems.			
46.	Please write in comments or describe mathematical shortcuts you may use in your trade			

APPENDIX B

Appendix B consists of a reproduction of the covering letter which accompanied the research instruments which were distributed to the sample subjects.

FACULTY OF EDUCATION
DEPARTMENT OF INDUSTRIAL AND
VOCATIONAL EDUCATION
TELEPHONE (403) 432-3678

THE UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA, CANADA
T6G 0Y1

Dear Sir:

I am currently teaching Automotives at St. Joseph Composite High School and am registered as a graduate student at the University of Alberta. Part of the requirement for a Master's Degree is the completion of an original research project. For my research topic, I have selected "Identifying Mathematical Competencies for Three Selected Trades".

Part of this study involves the collection of data relating to the Motor Mechanic trade, the Heavy Duty Mechanic trade, and the Welder trade. The design of the study calls for data to be obtained from journeymen presently functioning in each of three categories of positions within each of the selected trades. These categories are "practicing journeyman", "supervisor", and "instructor". The practicing journeyman category has been divided into two groups depending upon years of experience since achieving journeyman status. The first group consists of journeymen with five years of experience or less while the second group is made up of journeymen with more than five years of experience since becoming certificated in their trade. Because of your present position or employment in one of the above categories, you have been selected to participate in this study.

Please find enclosed a questionnaire that should take one half-hour of your time to complete. You will find directions for completing the instrument at the top of the first page.

When you have completed the questionnaire, please place it in the stamped self-addressed envelope and return it to me by December 31, 1976.

All information will be treated as privileged and will be made available only to the researcher.

It is anticipated that your valued opinions will contribute to the design and improvement of mathematics courses offered to students enrolled in the high school vocational education programs in Automotives and Welding.

An abstract of the study will be sent to all who return a completed questionnaire.

Yours sincerely

G. Verret

Gilles C. Verret

GCV:ov
encl.

B30190